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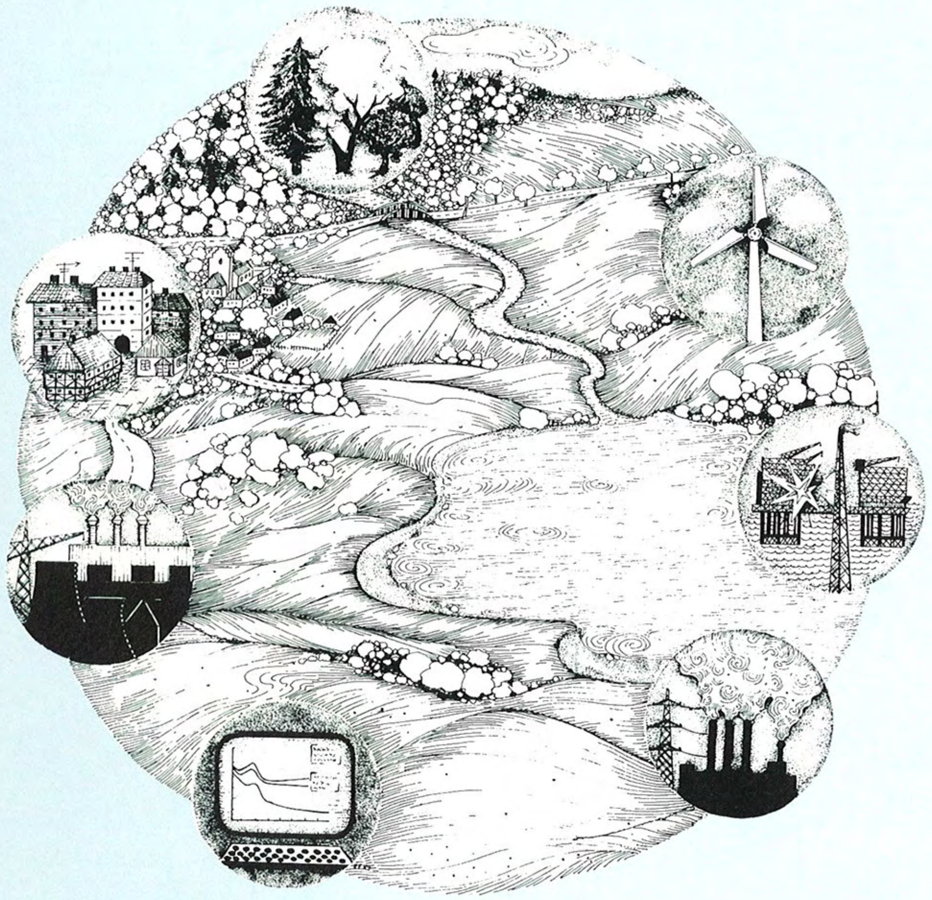
Edited by Hans Larsen and Kurt E. Petersen



Risø National Laboratory, Roskilde, Denmark
February 1993

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Abstract The report describes the work of the Systems Analysis Department at Risø National Laboratory during 1992. The Department is made up of the Cognitive Systems Group, the Risk Analysis Group, the Energy Systems Group and the UNEP Collaborating Centre for Energy and Environment. The report includes lists of publications, lectures and staff members.

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Contents

1 Introduction

The Systems Analysis Department undertakes R&D concerning methods and models dealing with the interplay among various technologies, systems and humans. The activities are directed towards the two research topics: **Energy and environmental planning and Safety and reliability of technical systems.**

The department, unchanged in organization since 1991, consists of four groups:

- Energy Systems Group (ESG)
- UNEP Collaborating Centre on energy and environment (UCC)
- Risk Analysis Group (RAG)
- COgnitive systems Group (COG)

of which the two first deal with research topic number one and the last two with the second research topic.

The level of activity of the department in 1992 has been very high. A number of major international research projects were completed, and several new have been initiated. The activities of the department in 1992 were financed 33% by government appropriations and 67% by funds derived from national and international research contracts and contract work.

The department is multidisciplinary, and the permanent staff numbers 38 engineers, natural scientists, economists as well as social and behavioural scientists, of which 13 are senior scientists, together with 3 Ph.D. students and 7 supporting staff. During 1992 one staff member has obtained the Ph.D. degree from the University of Aarhus. By the end of the year two new Ph.D. students have been engaged and will start their projects in the beginning of 1993.

The work of the department involves close collaboration with Danish and foreign universities, research institutes and industrial companies, as well as national ministries and international organizations such as the Commission of the European Communities, Nordic Council of Ministers, IEA, IIASA and UN/UNEP.

The Energy Systems Group undertakes research on methods and models for energy and environmental planning and assessment of energy and environmental technologies. The work in 1992 has primarily been a continuation of previous activities, with an expansion of the energy/environmental planning activities in developing countries. In addition, new initiatives have been successfully launched on basic research concerning the interplay between »bottom-up« and »top-down« modelling approaches.

The UNEP Collaborating Centre on energy and environment has the overall aim of promoting the incorporation of environmental considerations into energy planning worldwide, particularly in developing countries. The Centre is financed jointly by the United Nations Environment Programme (UNEP), the Danish International Development Agency (Danida) and Risø. In 1992 a new contract was signed for the second phase of the Centre running up to the end of 1994. A major activity of the Centre in 1992 was work on the project undertaken for UNEP to establish methodological guidelines for calculating the costs of limiting greenhouse gas emissions from the energy sector.

The Risk Analysis Group conducts research on the reliability of complex systems, consequence modelling and risk management. The activities involve development of tools and methods as well as their practical application. To a large extent the activities in 1992 have been centred around a number of CEC research projects under STEP and TELEMAN launched in 1991. An important event by the end of 1992 was the successful completion of the development of STARS: Software Tool for Analysis of Reliability and Safety.

The Risk Analysis Group was responsible for organizing the European Safety and Reliability Conference '92, which took place 10-12 June 1992 in Copenhagen. The conference attracted 270 participants from all over the world.

The Cognitive Systems Group is engaged in interdisciplinary research on usercentred information systems. In 1992 a major achievement has been the successful completion of the ESPRIT project ISEM and the ESPRIT basic research project MOHAWC. Together with the Centre for Cognitive Science at Roskilde University Centre the group has created the Centre for Cognitive Informatics in 1991. Its aim is to share and coordinate research activities, and in 1992 several successful initiatives have been taken in relation to new CEC-funded research projects and other activities.

2 Risk Analysis Group

Disturbances at industrial plants can cause severe interruptions leading to major economic losses and in some cases to accidents threatening human lives and property. The CEC has funded research programmes emphasizing these topics focusing on identification, analysis and prevention of failures. The Risk Analysis Group (RAG) has contributed significantly to these programmes in 1992 through its work on reliability analysis, consequence modelling and risk management.

An important event in 1992 was the completion of the development of the STARS software tool intended for reliability and safety analysis. A prototype of the software tool has been developed and presented at a workshop at JRC-Ispra in December. One major achievement is the integration of qualitative analysis and subsequent detailed fault tree analysis. A problem which is still unsolved is the identification of hazards and accident sequences at plant level, which is a theme of the current CEC project TOMHID.

In 1992 the effort on integration of reliability analysis into the design process and in maintenance planning was continued. Reliability techniques are applied in the development of a robot to work in disordered nuclear environments within the CEC TELEMAN research programme. A demo-system was developed with the purpose of supporting maintenance planning based on failure reports and condition monitoring data from process control measurements. The advantages of the system were illustrated investigating the main and the auxiliary feedwater systems at the Barsebäck nuclear power plant in Sweden.

The work on consequence modelling in 1992 has concentrated on fire product characterization and gas flame experiments. The CEC project on risks from fires at chemical plants aims at characterizing fire products from warehouse fires. In 1992 a database on past European warehouse fires has been established and a series of microscale experiments with selected chemicals has been carried out, both with the purpose of identifying relevant fire scenarios and planning the full-scale tests to be carried out in 1993. Medium-scale experiments with natural gas jet flames have been carried out with the aim of describing free flames and flames impinging on an object like a vessel. The work in 1992 focused on finalizing the construction of the test facility and the first series of experiments determining the temperature field, flame geometry, heat radiation and heat transfer to an obstacle. A thorough data analysis is planned for 1993.

Within risk management two important activities in 1992 were the work on life cycle analysis and safety report requirements. Life Cycle Analysis is a topic that draws increased attention. In the Danish programme for integrated assessment of environmental and occupational impacts of new materials a screening procedure developed by Risø dealing with accidental impact has been tested in 1992. The results verified its applicability and identified a major problem when analyzing a planned production at a stage where a lot of details are lacking. A report summarizing the work financed by the Nordic Council of Ministers on requirements on safety reports has been issued in 1992. The report describes the Nordic experience and future trends for the preparation of safety reports. The objective of the work was to develop a common Nordic set of requirements implying a harmonized Nordic approach to the contents of a safety report.

Finally, RAG has participated in developing a standard for risk analysis to be issued by Danish Standards Association in 1993. It also has a seat in the CEC advisory committee SHARE (Safety Management and Hazard Assessment Research Cooperation in Europe), which supports the CEC in identifying research needs and priorities and has initiated an activity on evaluation of models used within the area of major industrial hazards.

2.1 Knowledge-Based Methodology for Hazard Identification at Plant Level

The objective of the project is to develop an overall knowledge-based methodology which will provide assistance and guidance to the user for hazard identification purposes and which will follow the course of an incident in every stage of the event chain.

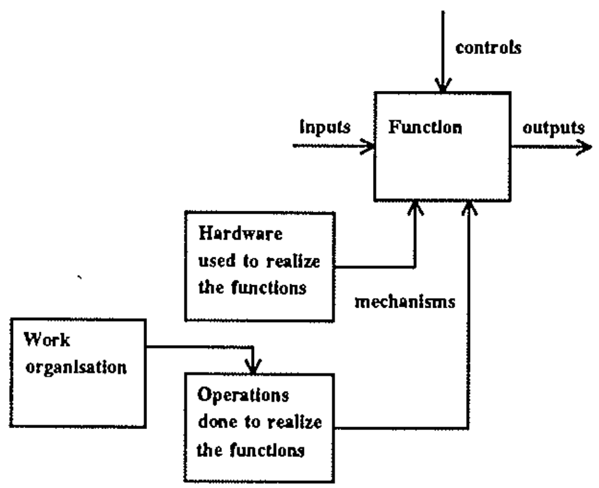
The project is funded by the CEC STEP-programme. It has been initiated in 1991 with a duration of three years. The project is carried out by an international consortium including the following partners: VTT (Finland), Risø, The University of Sheffield (UK), SRD (UK), CIEMAT (Spain), Tecsa (Italy) and Joint Research Centre (Italy).

One of the major objectives of the project is to provide a comprehensive framework to represent a process plant as a socio-technical system, i.e. considering the components, operator interventions and management, and the methodology is intended to be used as a first stage in the hazard identification process. This will identify critical areas and the need for further analysis using well-established approaches.

The general paradigm chosen to describe a socio-technical system is a functional breakdown inspired by the Structured Analysis and Design Technique (SADT). The intention is to develop a framework representing a socio-technical system as a hierarchical object-oriented structure. The working principle of the hierarchical structure is to start at the top level where the overall plant function is defined (e.g. »Production of the chemical substance XX«). At the next level this function is decomposed into its main constituent elements (e.g. »Storage«, »Processing«, »Provide raw materials«). The decomposition analysis is continued and refined at the subsequent levels until an appropriate level of detail has been achieved.

The plant model follows a general framework as indicated in Figures 2.1 and 2.2 The basic idea is that a set of plant functions links together hardware, operations and the work organization. In the framework it will be possible to integrate information and knowledge about the technical, physical and functional configuration of the plant together with relations and connections to the operational organization and its superimposed management aspects. In this way the methodology has a strong advantage compared to the traditional piping and instrumentation (P&I) diagram. The model will be used to support a high-level hazard identification intended to operate in two different modes.

Figure 2.1. Basic principle for functional, object oriented modelling.



In mode I the objective is to carry out a **concept hazard analysis** which will be performed as a structured group session supported by checklists and keywords (e.g. flammables, explosives). The results from this mode will be a document containing an identification of the plant units that are critical from a safety point of view. The tool will provide the checklists and keywords and contain the resulting conclusions of the group session.

Mode II contains the **high-level hazard identification based on a functional plant description.** In this mode the analysis is extended based on the experience gained in mode I and other information sources. The plant model follows the principles indicated in Figures 2.1 and 2.2. In carrying out the analysis the user will be supported by a knowledge-based tool comprising a model editor and a set of databases containing information on functions, equipment, operations, management, substances etc. The analysis will pass through the following steps:

a. Creation of a socio-technical plant model.
b. Hazard identification.
c. Hazard analysis
   - identification of immediate causes
   - identification of root causes
   - consequence assessment.
d. Risk ranking.
e. Mitigation proposals.

The contribution from Risø has in 1992 been concentrated on the conceptual study on the development of the socio-technical plant description. The emphasis has been laid on a detailed development of an operations taxonomy to be implemented in the operations database. The basic idea of this part of the hazard identification tool is to provide a taxonomy which can be used for the stepwise decomposition of the operations in the functional model leading towards elementary operations appropriate for failure and cause analyses. Furthermore, a case study has been carried out in order to illustrate how the modelling principles work in practice. In the next phase the

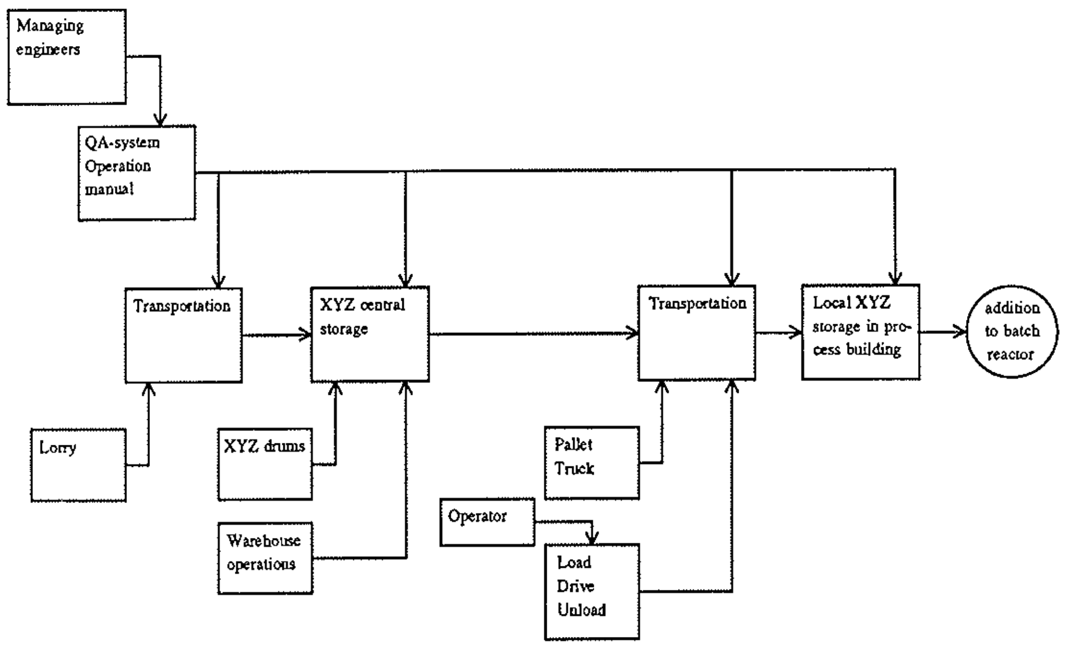


Figure 2.2. Example of functional modelling.

functional architecture of the tool will be defined in order to implement the methodology.

2.2 Reliability Analysis of an Advanced Robot

Together with partners in Belgium, Germany and Great Britain RAG runs the project ENTOREL (ENvironmental TOlerance, RELiability and safety). The project is part of the CEC TELEMAN research programme. The objective of TELEMAN is to develop advanced teleoperators (robots) that can operate in hazardous or disordered nuclear environments.

The robots aimed at in TELEMAN will be more or less autonomous, meaning that they will be performing their tasks without continuous control by an operator. Taking into consideration the hostile environments foreseen, the aim must be that a robot does not break down totally during work, since recovery of a stranded machine may be difficult, if not impossible. Therefore, reliability has been analyzed and failure strategies formulated in order to ensure that the robot returns to a safe state and location when faults occur.

Representative tasks to be performed by the TELEMAN machines are materials handling, maintenance, repair, radiation and contamination measurements, decontamination and decommissioning. Environmental and operational demands to be met by the machines include radiation tolerance up to 10^6 Gy total dose and resistance to fumes and splashes of HNO_3 and other decontamination fluids.

In 1992 the reliability study concentrated on a gantry-type of machine as outlined in Figure 2.3. The robot itself is mounted on a telescopic mast which is pneumatically operated. This elevator is mounted on a transverse carriage which runs on the gantry travel bridge. In the analysis, failures of three different types are considered: *equipment failure, human error and organizational error.* The influence of each of these types differs, depending on the operational mode of the machine, which is either a manual, semi-autonomous or autonomous mode.

As the first step of the reliability analysis a failure mode and effects analysis was carried out. From this analysis it was realized that for nearly all failures identified, a radiation-induced failure cause can be identified in addition to the »conventional« ones. The relative importance, however, is not addressed in the FMEA.

Based on the result of the FMEA a fault tree was constructed for three failure scenarios: that of a drilling operation, a decontamination operation and an ultrasonic inspection. The three major top events studied are: robot inaccessible in

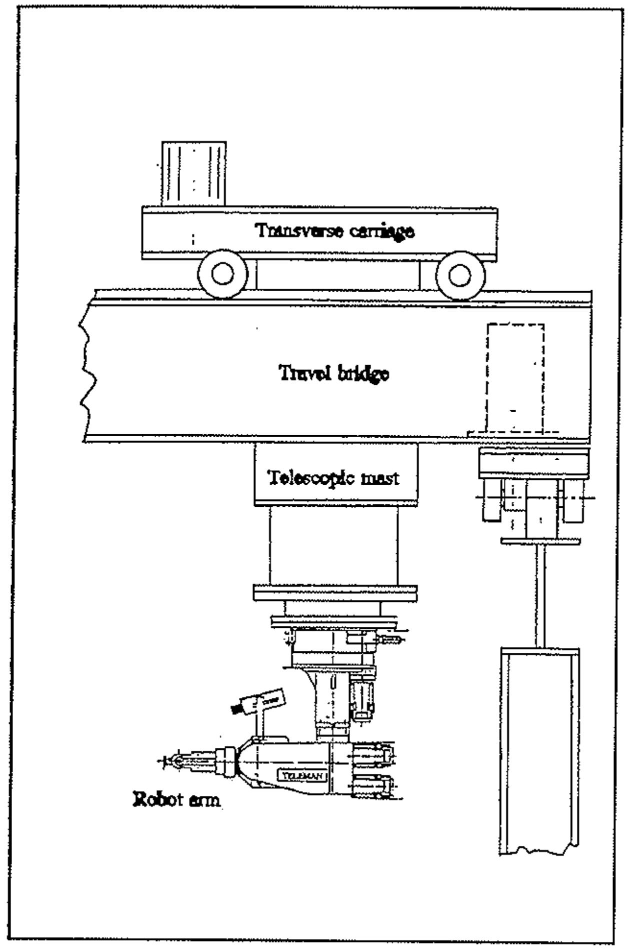


Figure 2.3. Sketch of the gantry type TELEMAN machine.

high radiation area, failure to perform a task making repairs necessary in a high radiation area and failure to perform a task with repair possible without radiation risk.

The qualitative reliability analysis has been carried through to a point where the results can be used to identify the need for design modifications and introduction of redundancies in order to prevent the machine from being stranded in a position where access is difficult or dangerous.

The failure strategy analysis was carried out in two steps. The first was based on the fault tree developed in the reliability analysis and comprised a systematic review of the fault tree corresponding to the top event: loss of the robot. During this first step a series of potential single failures was identified in the motion systems, which could lead to the top event analyzed.

After these failures were identified, a modification in the design of the motion system was suggested by introducing redundancies that remove the possibilities for the occurrence of the above top events as consequences of single failures. A fault tree for the modified machine was constructed. The modified system was analyzed for common cause failures (CCFs), of which in total 13 possibilities were identified, and cut sets were calculated. In many applications the probability of a CCF is judged to be in the range of 0.05-0.15 times the corresponding single event probabilities, but in this system ionizing radiation acts as an additional contributor to the CCF causes. On the other hand, condition monitoring serves to counteract both single events and common cause failures.

The cut sets were reviewed systematically. During this review proposals were made for additional measures against failures relative to the ones implied in the design basis and the assumptions underlying the reliability analysis. The proposed measures are divided into two parts: preventive measures and consequence mitigating measures. An example of a preventive measure concerning the design phase is:

- Condition monitoring should be applied, for instance to the integrated gamma dose to components especially susceptible to radiation damage and to the current and temperature in the windings of important motors.

Even though »hard« reliability data may be missing, it is possible to use a qualitative reliability analysis like this one for identifying those components and systems that have a pronounced impact on the reliability of the overall system, and for proposing improvements in the design and operation of the machine in order to secure the reliability of robots in high radiation areas.

2.3 Toxic Gases from Chemical Warehouse Fires

Over the years a large number of fires have occurred at industrial installations. In these fires large amounts of chemicals may be involved with the possible formation of significant amounts of toxic products. These might be dispersed with the fire plume causing harm to humans and the environment. Today only limited documentation is available concerning the assessment of the potential risks from fires at chemical plants and warehouses. This is mainly caused by a general lack of knowledge on the chemical nature and the amounts of the toxic substances that can be generated.

The research project entitled Combustion of

Chemical Substances and the Impact on the Environment of the Fire Products has been initiated in order to remedy some of these problems. The project is sponsored by the CEC STEP programme. It is a three-year project initiated in 1991. The participants are: Risø, which acts as project coordinator, South Bank Polytechnic (U.K.), VTT (Finland), SP - Swedish National Testing and Research Institute (Sweden) and Lund University (Sweden).

The objective of the project is to obtain data concerning the identification and quantification of the fire products from fires in warehouses containing commercial chemicals. The project comprises experiments of various scale in order to identify the source term characteristics and the relation between bench-scale testing and real fires. The ideal end-goal of the project is to develop a test protocol to be used for assessing fire risks from chemical installations.

Risø and VTT have constructed a database covering the chemical warehouse fires which have occurred in Europe during the last ten years. In relation to the planning of the combustion experiments within the project, the database has been used in order to identify the scenarios which are to be simulated in such a way that they reflect past incidents.

Risø is responsible for the microscale experiments. The work has been undertaken by the Risk Analysis Group and the Combustion Chemistry Group in collaboration. In 1992 the experiments have been carried out using a combustion furnace in accordance with the DIN 53436 standard. Different types of chemicals have been subjected to combustion at various conditions in order to simulate different fire scenarios. The substances investigated are: a chlorinated pesticide, a chlorophenoxy pesticide, three different organophosphorous pesticides, a chlorinated solvent, a fertilizer and different types of polymers. The concentrations of the combustion gases such as carbon dioxide, carbon monoxide, sulphur dioxide, nitrogen oxides, hydrogen cyanide, ammonia and hydrochloric acid have been determined, and the organic combustion products have been identified.

One major conclusion is that the method used by Risø is suitable for the simulation of two different fire scenarios. These are the well-ventilated, fully developed fires and the oxidative, smouldering fires. Fires categorized as developing fires cannot be simulated. However, it should be noticed that a microscale test cannot fully model the complex growth and development of a full-scale fire.

The results of the work are currently used when planning the medium- and full-scale experiments carried out by the other partners in the project. Later on when the experiments in the various scale have been carried out the scaling effects are to be evaluated.

Linked to this work a Ph.D. study entitled »Toxicity of Smoke from Fires in Chlorinated Chemicals« was initiated in 1990. In 1992 the experiments using the DIN 53 436 furnace and the associated chemical analyses of the combustion products have been completed. Based on the results of the chemical analyses one of the substances subjected to combustion has been chosen for further toxicological investigations. These animal inhalation experiments will be carried out at the Royal Danish School of Pharmacy. The Ph.D. study will be completed in 1993.

Publications in 1992: 58 and 59.

2.4 Gas Flame Temperatures

In industrial societies large quantities of flammable gases, such as natural gas or propane, are produced, stored and distributed. Although their flammability is a valuable property, these gases are hazardous materials. Research into the safe handling of flammable gases goes on in all industrialised countries, and since it can be quite costly to make experiments, the activities are coordinated internationally.

Risø participates in the CEC project, called JIVE, which aims at studying one particular type of accident scenario in which a pressurised tank containing liquefied propane gas is heated by a gas jet flame. The tank eventually fails due to weakening of the steel and the building up of pressure as the propane begins to boil, and the propane is released suddenly into the fire producing a gigantic fireball (a so-called BLEVE). 12 groups from 8 European countries are working together on different aspects of the modelling of this accident scenario and of the effectiveness of various mitigating measures. The work covers experimental and theoretical studies of a wide range of phenomena, such as the dynamics of jet fires, two-phase jets, the formation of droplet aerosols, soot formation, effects of fuel composition, heat transfer from a flame impinging on an objects, the effects of flames on flange connections, the boiling process taking place within a heated pressurized tank and effectiveness of water spray cooling and insulation materials. One group even makes full-scale experiments in which large propane tanks are placed in a gas jet flame and heated until failure - a direct simulation of the accident.

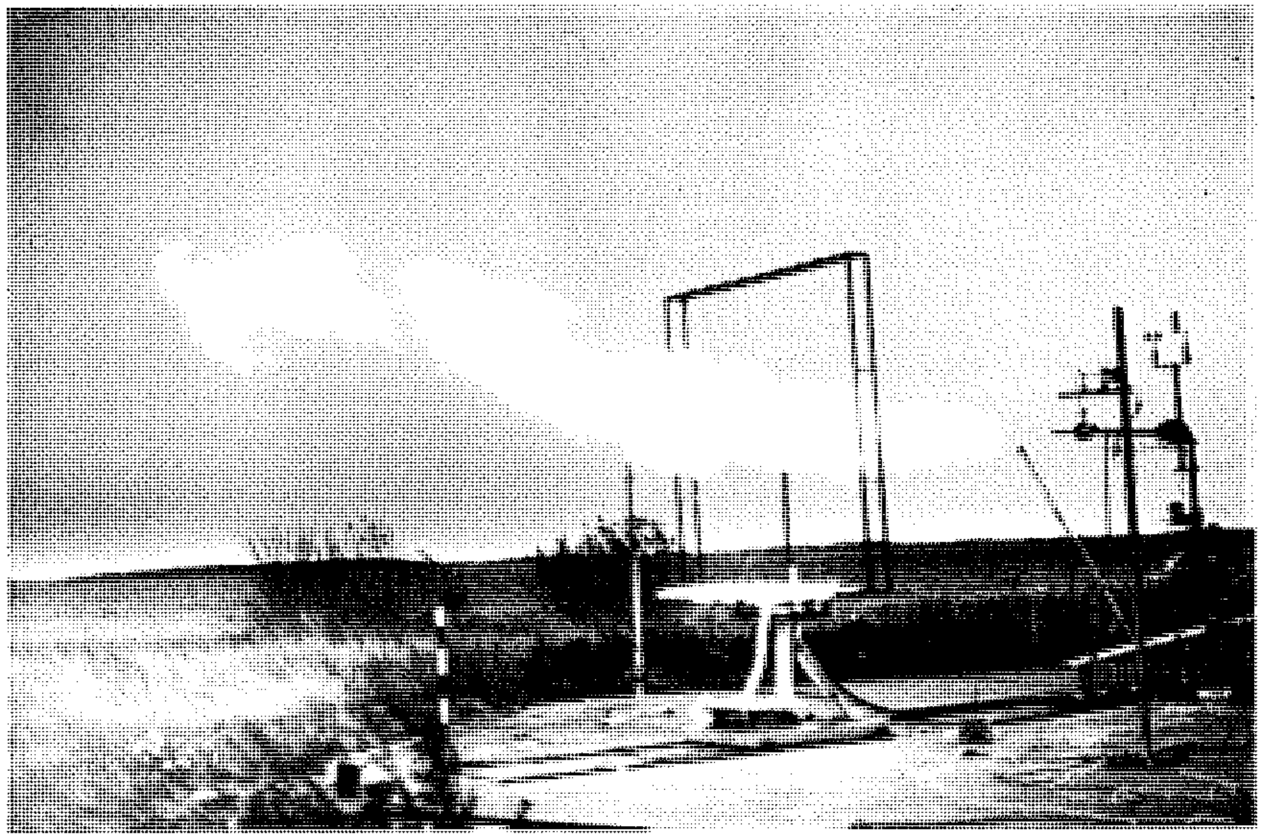


Figure 2.4. A flame experiment carried out at Risø's test facility. The flame shoots through a metal frame supporting 64 thermocouples.

Risø's part of the work, which is carried out by RAG in collaboration with the Department of Combustion Science, is to perform experiments with natural gas jet flames at our test facility, where 8-meter long horizontal natural gas jet flames can be made, Figure 2.4. The primary purpose is to provide data for evaluating jet flame models. We measure flame temperatures, heat radiation from the flame, heat transfer to simple objects (hollow plates and cylinders), make infrared images and plan to make laser sheet visualisations. In 1992 the main work has been concerned with measurements of the temperature distribution in the flame.

The comparison between theoretical predictions and measurements is tricky in these types of experiments owing to the chaotic nature of atmospheric turbulence. During an experiment the wind direction is supposed to be aligned with the flame, but the turbulence makes it fluctuate causing the flame to bend and meander in a random way that no theory can predict in detail. The temperature measured with a sensor placed at a fixed point in general wildly fluctuates, Figure 2.5, and the wide range of the fluctuations obviously influences the heat transfer to objects in the flame. The explanation for the fluctuations could be that the flame is bent by the wind. This is essentially a meteorological effect to which we will refer as meandering. The fluctuations could also be intrinsic, i.e be caused by more complex changes of the shape of the flame or be a result of instabilities. In the latter case the fluctuations would be caused by turbulence generated in the flame and be less dependent on the presence of atmospheric turbulence. The meandering is not included in the theoretical models, whereas intrinsic fluctuations should be regarded as included, but averaged out, since the models are formulated in a time-averaged setting. Therefore, a careful interpretation of the experimental results has to be made before comparing them with theory, and the design of the experiments should allow for this.

In order to make it possible to filter out the flame meandering, we made a two-dimensional array of 64 thermocouples that could measure temperatures simultaneously in a square area perpendicular to the flame axis. The whole arrange

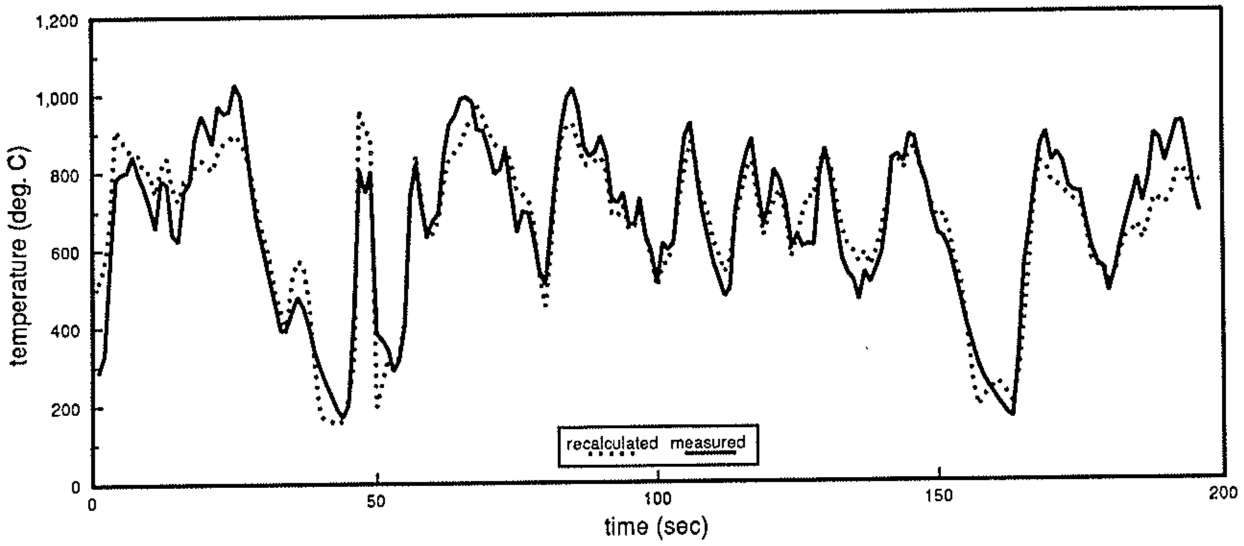


Figure 2.5. A typical example of a measured flame temperature time series (solid line). The dotted line shows the result of recalculating the time series assuming a fixed flame shape.

ment is placed on rails so that it can be moved between positions down the flame axis, Figure 2.4. In a typical experiment the thermocouple array is parked at 8 different positions for a few minutes at each place. With a bit of luck the wind speed stays constant during the experiment, and we get 8 data sets, each containing 64 time series of simultaneous temperatures representing the temperature distribution in a slice perpendicular to the flame axis.

In the data analysis each slice was considered separately. With 64 temperatures at a time it is possible to establish the left/right and up/down displacements of the flame centre as a function of time. The moving centre defines the origin of a coordinate system that moves together with the flame position, and a smooth distribution can then be fitted to all data, Figure 2.4. Thus the raw data - consisting of 64 time series each containing some 500 temperatures - is boiled down to a single temperature distribution plus time series for the meandering of the flame centre. The next step is to recalculate the temperatures on the basis of the fixed distribution plus the moving centre. The recalculated temperatures then represent a flame which is meandering, but has no intrinsic fluctuations. It is surprising how well the recalculated temperatures fit the corresponding raw data series, Figure 2.5. This demonstrates quite clearly that the meandering is by far the most important source of fluctuations, and in spite of the seeming irregularity of the raw data, the shape of the flame is nearly constant in time, except for the displacement of the centre. This fixed shape is what should be compared with model predictions. A further confirmation of this picture is the observation of a strong correlation between the horizontal displacement of the flame centre and large-scale wind direction fluctuations. These results are good news for modellers, since it turned out that the intrinsic fluctuations, which are extremely difficult to model, are not very important here, and that the meandering is related in a fairly simple way to large-scale atmospheric turbulence.

2.5 STARS: Software Tool for Analysis of Reliability and Safety

The STARS project was completed in 1992 with the full integration of all the software modules created by the four partners and a subsequent demonstration of the functionality of the qualitative analysis example for a plant producing nitric acid by combustion of ammonia. The project took 3 years as planned. The participants were The JRC Ispra, the Technical Research Centre of Finland, the Italian company TECSA and Risø.

The software package produced is bringing the domains of artificial intelligence and advanced information processing into the field of safety and reliability analysis in a more application oriented way than has been seen in earlier systems such as RIKKE and CAFTS. The powerful data processing and graphic capabilities of work stations are facilitating an interactive working procedure in the analysis. RIKKE and CAFTS were automatic fault tree generators, whereas STARS is an interactive analysis support tool to enable the analyst to use plant and process descriptions as well as information about chemical substances and reactions for qualitative analysis and for detecting top events to be treated by the automatic fault tree generation. Today STARS aims at the analysis of chemical plants. The use of STARS for energy conversion plants has been discussed, but this will require the inclusion of other types of knowledge and changes in the qualitative analysis program.

The support information is drawn from a set of knowledge bases, i.e. the 3 chemical knowledge bases for substances, reactions and unwanted reactions, as well as 2 knowledge bases for the plant, viz. a component knowledge base and a unit knowledge base.

There are editors for drawing plant piping and instrumentation (P&I) diagrams and plant flow diagrams. Fault trees can be derived automatically by an inference engine working on plant and component data, which for this purpose are defined by means of rules.

The qualitative analysis program works on the plant flow diagram and acquires knowledge from the chemical knowledge bases. Part of the chemical knowledge is stored as tables of physical- chemical data, while the expert knowledge is stored as rules. The qualitative analysis program is partly based on checklists and guideword lists, and partly on a graphical method much like the HAZOP method.

The STARS program package also comprises a module for assessing the consequences of hazards identified, i.e. physical properties such as temperatures and concentrations. A module for vulnerability calculations is also included for assessing final effects on persons, buildings etc. in the vicinity of an accident.

The main responsibility of Risø has been to develop the above-mentioned knowledge-based support systems for chemical substances and reactions. The knowledge bases contain generic knowledge, while specific knowledge for actual plant applications will have to be provided locally before an analysis can begin. The chemical substance knowledge base contains a database that describes the physical, chemical and toxological properties of the substances as well as sets of rules describing their potential hazards. The chemical reaction knowledge base contains general descriptions of the reactions and sets of rules which relate specific classes of substances to the generic hazards and the conditions for the hazards to occur. The unwanted chemical reaction base contains a reaction matrix on rule-form. By means of that it can be assessed if an unwanted mixing of two chemical substances can cause any hazard. These knowledge-based systems can be queried for information by other parts of the STARS system, but user interfaces are also provided, so the system can be used stand-alone. Figure 2.6 visualizes the screen display in the middle of the analysis of generic hazards for a substance.

Risø developed the knowledge bases and a dedicated inference engine for the reasoning in the chemical rules.

The STARS partners have agreed to continue with some enhancements, the presence of which became clear during the project. For the chemical data some thermodynamic models would be very useful, as processes take place at many other than the so-called standard conditions. A more direct correspondence between P&I- and flow diagrams would also be very useful in the process of deriving fault trees.

The use of the STARS project results is foreseen in an application for a project proposed to the CEC ENVIRONMENT programme. This new project will use STARS as the tool in a risk management system for chemical plants. Publication in 1992: 50.

2.6 Pilot Study on Maintenance Indicators

Under the Nordic Nuclear Safety programme NKS/SIK1 a pilot project was carried out on developing indicators which can be used for maintenance planning, exemplified at the Barsebäck nuclear power plant.

The maintenance indicators should give information about aging and degradation of components prior to complete component failure.

The systems selected for the pilot project were the main feedwater system and the auxiliary feedwater system representing components in a continuously operating system and a standby- or safety system, namely the feedwater pumps and steam isolation valves, respectively.

Main Feedwater Pumps

The study of the main feedwater pumps was per

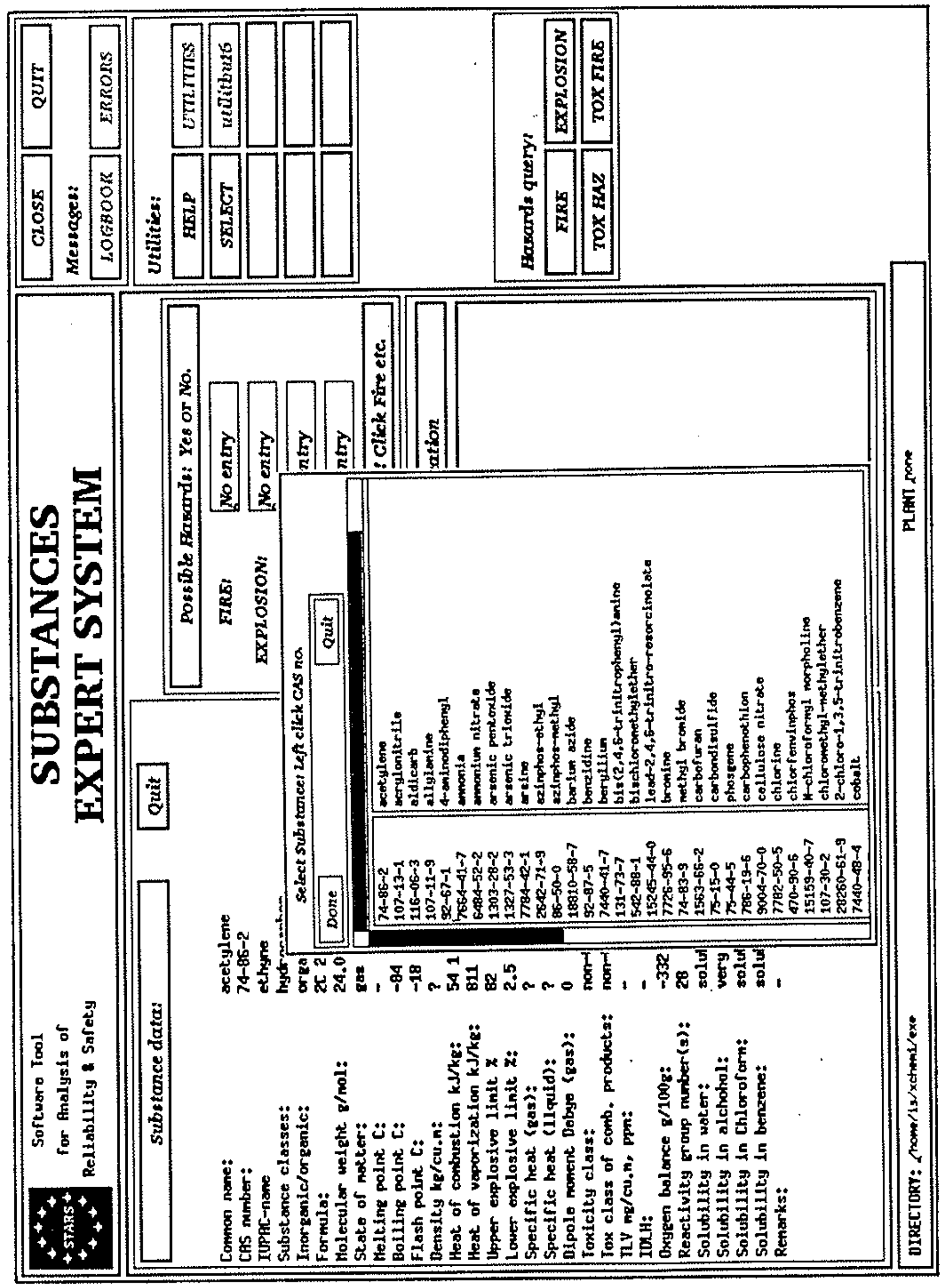


Figure 2.6. Screen display

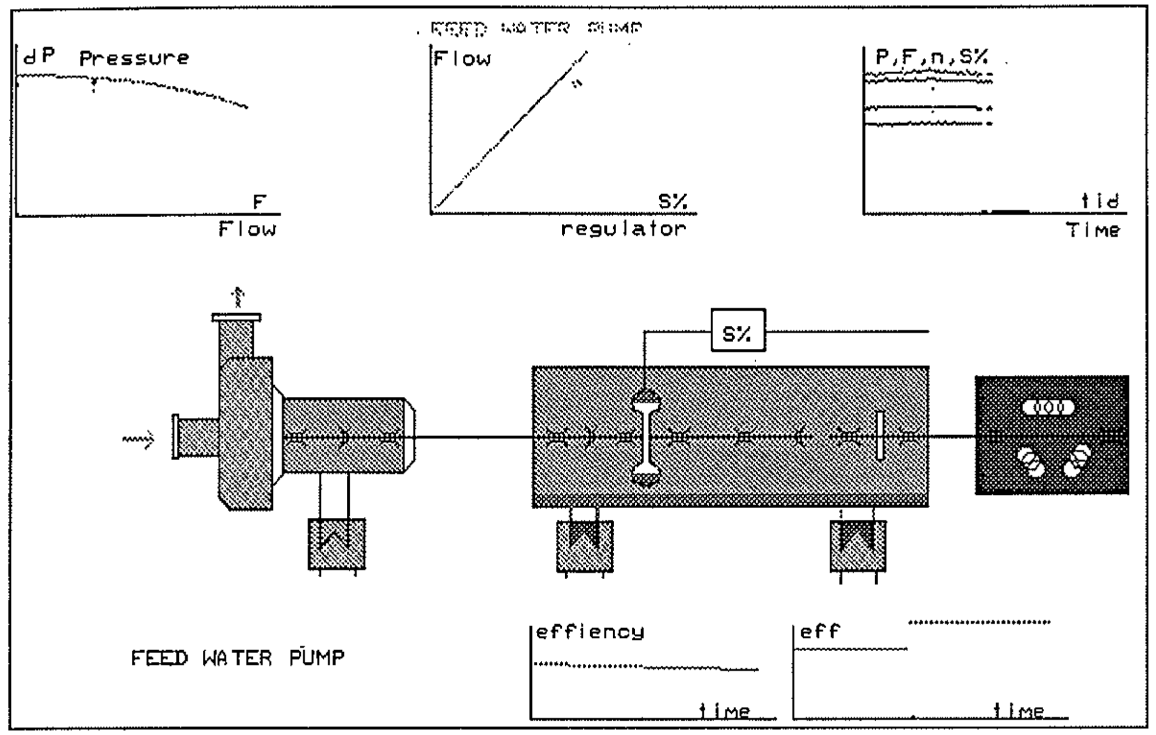


Figure 2.7. Main feedwater pump system.

formed on the basis of information extracted from the Swedish component failure reports (ATV), the local maintenance planning system, the description of and requirements on the pumps and the process data stored for a 120-day period.

It was demonstrated that indicators which show deviations from initial operating characteristics can be developed by the use of process data. Deviations from initial operating characteristics are an indication of a change, due either to wear or other kinds of degradation of the component itself, or non-optimal operation due to a failure of another component in the process plant.

Figure 2.7 shows the display from a PC demo program where the pump characteristic, the controller characteristic and the efficiency of the pump oil coolers can be seen as well as the current position af the operating performance of the component.

From data in the ATV-reports and the local maintenance planning system, statistical methods have been used to elicitate changes which can be indications of degradations of the components, such as changes in failure frequencies which can be illustrated graphically by a TTT-plot or changes in the unavailability as function of time. A demo program has been developed for the purpose of studying the components historically, facilitating the possibility of comparing similar component histories for possible deeper investigations of the problem if some of the components differ from the others.

Steam Isolation Valves

Concerning the steam isolation valves the data available for the study were the closing times at tests, the ATV reports and the reports from the local maintenance planning system.

From the measured closing times it is possible to follow the measurements from test to test, Fig 2.8, and also to compare the closing times for similar valves. As seen from the figure, test no. 9 is different from the other tests, probably due to a failure in the test equipment and not in the steam isolation valve system. This type of presentation gives a good indication of trends over time and among components in the population.

The work done until now in the pilot project shows that the data stored at the plant can be used for purposes other than that for which they were intended. The process data can be used for condition monitoring purposes, but also for the daily supervision of the condition of the plant. The failure and maintenance reports can be used to look at component histories, and detailed studies of the reports give input to the long-term planning of the maintenance work.

Publications in 1992: 37.

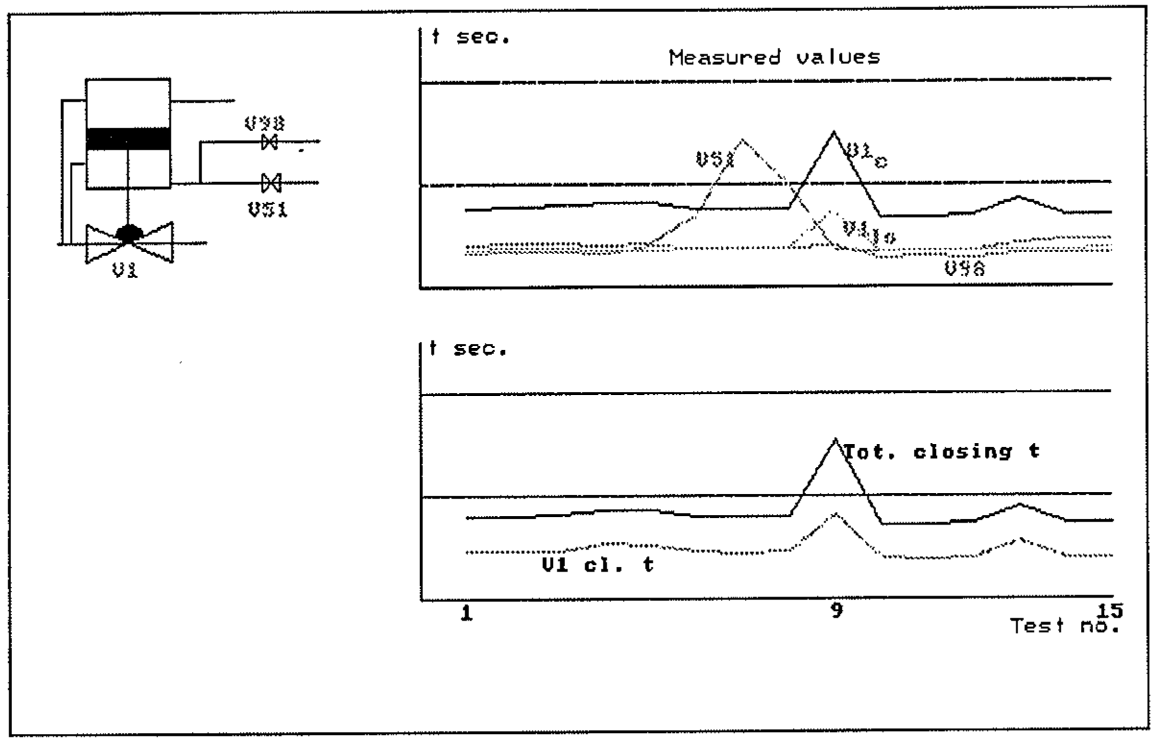


Figure 2.8. Time measurements on a steam isolation valve closing test.

2.7 Specific Risk Analysis Applications

The methods and models developed for the purpose of reliability and risk analysis were applied in a number of projects in 1992 of which two will be described. One of the projects dealt with a risk analysis of various options for import of raw materials to a fertilizer plant, the other one the probability that a ferry will run aground in a harbour.

Import of Raw Materials to Fertilizer Plant

Under contract with RH&H Consult of Denmark, a risk analysis of various options for import of ammonia and phosphoric acid for an Indian fertilizer factory has been carried out. The risk analysis is part of a techno-economic feasibility study which RH&H has been commissioned to perform for the Danish International Development Agency. The background to the feasibility study is a planned doubling of the capacity of the fertilizer factory, combined with the limited capacity of the existing import facilities.

The risk analysis concerned the hazard aspects associated with the handling of ammonia in four main alternatives for increasing the import of ammonia and phosphoric acid:

- improvement of the existing import system which includes rail transport of ammonia and phosphoric acid from a port terminal to the factory, a distance of 200 km
- import via a new port not far from the factory
- import via a separate pier at the factory
- an offshore intake system outside the factory with subsea pipeline connections.

The aim of the analysis was to carry out a comparison of the alternatives as regards to the danger to which people are exposed from the potential of accidental ammonia releases. To make this comparison possible, risk indices for the ammonia handling activities of each alternative were derived on the basis of (1)estimated frequencies of major ammonia releases and (2)the number of people who might be exposed to lethal doses.

The comparison analysis indicated that import via a separate pier or an offshore intake system are the most favourable alternatives from a safety point of view.

The rough risk index method proved to be an efficient approach when assessing the risk connected to alternatives, given the very limited resources and information available. The results together with similar results from other assessments in the techno-economic study will form

the basis for a selection of the most appropriate option, where a more thorough risk analysis will be carried out.

Running Aground in a Harbour

For Danish Maritime Institute, Lyngby, a method was developed for calculating the probability of a ship running aground in a habour.

The method takes into account the variations in the water level due to waves, current and tidal water in addition to the vertical motions of the ship due to waves and speed. The method was used for estimating the probability that a ferry runs aground in the harbour of the town Hirtshals in Denmark.

The probability of running aground was calculated as the probability - per approach or departure - that the draught of the ferry exceeds the water depth. The calculations were carried out with two different speeds - 4 and 6 m/s - for approach to as well as departure from the harbour.

Figure 2.9 shows the cumulative distribution function for the water depth and the density distribution function for the resulting draught of a ferry corresponding to one of the calculations made for a ferry approaching the harbour with the speed of 4 m/s. The probability of running aground for the case was calculated to be 2.3×10^{-5} per approach of the harbour. Assuming one approach per day the result means, that the ferry will run aground with an interval of approximately 120 years.

The method has further potential for other applications, for instance, optimization of dredgings and assessment of the number of days per year in which a ship cannot enter the harbour, and for supply of input to overal economic calculations.

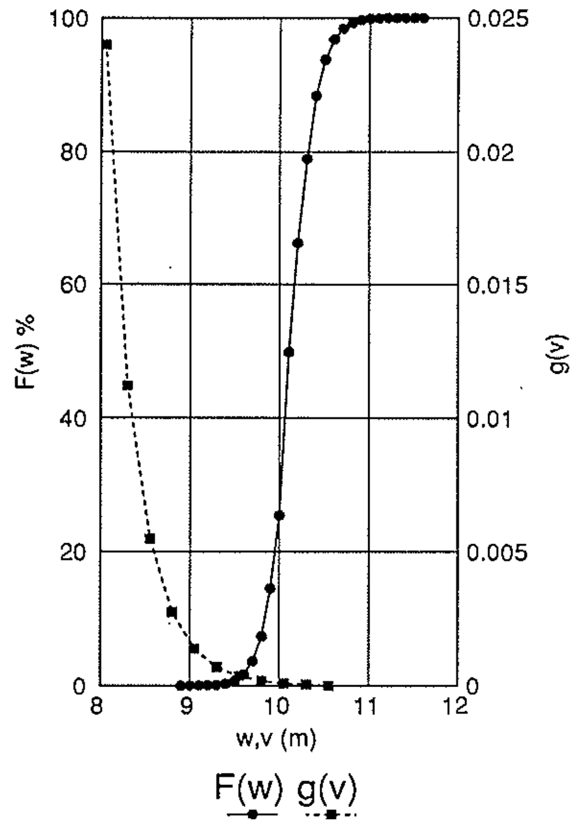


Figure 2.9. The distribution functions F(w) for the water depth and g(v) for the draught of the ferry.

3 Cognitive Systems Group

The key research issue in the Cognitive Systems Group (COG) is the multitude of problems that arise when computer artifacts are inserted between people and their work. Generally speaking the activities in the group focus on the development and demonstration of user- centred IT design principles based on field studies of work requirements, tasks, user competencies and user preferences. Work and task analysis, studies of cooperative work arrangements and investigation of human cognitive behaviour in complex situations involving search for information, communication, problem solving and decision making are characteristic ingredients of this approach to the design of system architectures and user interfaces. The group takes a special interest in human reliability in high-tech work environments in which efficiency and safety are all-important design considerations. IT for support and training of personnel in emergency-management organisations and within the medical sector are main items on the group's R&D agenda.

In 1991 the group entered a partnership with Centre for Cognitive Science at Roskilde University to form Centre for Cognitive Informatics (CCI). The intent is to promote the integration of cognitive science into the concepts and methodologies of system design with a view to creating a unified environment the main components of which are basis research, application-oriented R&D, training of researches and dissemination of information. The move to amalgamate the expertise and resources at Risø and Roskilde University in the fields of cognitive science and human-computer interaction is justified by the combined availability of some 25 researchers with widely different professional backgrounds, by the improved chances of such a relatively large group to obtain funding from national and international research programmes and by the proximity of the two institutes. CCI is monitored by an external committee with representatives from Danish science and industry.

CCI's research is focused on the topics: (1) interface design principles and multimedia, (2) models of human cognitive peformance, (3) speech and natural language, (4) computer- supported cooperative work (CSCW) and (5) diagnosis of technical and medical systems. The activities are financially supported by a framework programme on cognitive informatics executed by the Danish Science Research Council and Danish Technical Research Council. In an international context CCI manifests itself by participating in projects, research networks and working groups within the CEC ESPRIT programme and other European cooperative efforts in the information technology (IT) area.

The funding from the framework programme has enabled the CCI partners to attach five scientists to the research programme and to set up a fully equipped multimedia laboratory at Risø. The purpose of the multimedia laboratory is to permit fast prototyping and evaluation of advanced interfaces involving the use of pictures, video and sound. The facilities include two high-performance Macintosh computers, an ultra-fast DOS machine, video cameras and video recorder, Gigabyte harddisk, optical disk, and colour scanner and colour printer.

In 1992 two CEC ESPRIT-II projects coordinated by Risø were terminated: MOHAWC (Models of Human Activities in Work Context) and ISEM (IT Support for Emergency Management. MOHAWC was an ESPRIT Basic Research Action carried out jointly with seven European universities and JRC-Ispra. The detailed results of the project have been published by Risø as workshop proceedings from four topical workshops held during the project period. Additional results are presented in a collection of MOHAWC Separate Papers. A successful effort has been made to produce an interaction between MOHAWC and the framework programme Representation and Processing of Knowledge executed by the Danish Research Council for the Humanities.

A significant contribution made by the Cognitive Systems Group to the MOHAWC project is a Taxonomy for Cognitive Work Analysis which defines the concepts and relations that associate user competencies and user preferences with work and task requirements. The implications of this theoretical framework for systems design are discussed in a comprehensive report included in the collection of MOHAWC Separate Papers. Empirical work carried out under the CCI framework programme to demonstrate the usability of the framework in the design of computer interfaces is described.

Extensive work was done in MOHAWC to demonstrate the aspects of simulated work settings ('microworlds') in empirical studies of human cognitive behaviour. An excellent opportunity to utilise this experience was provided in a project in which the Cognitive Systems Group assisted the Danish Maritime Institute with establishing performance criteria in a training programme set up for ferry navigators in an advanced ship simulator on the Use of Microworlds in Training, Education and Research organised by the University of Bamberg and held on 20-22 May 1992 in Lübeck. Further work on the development and use of training simulators for cognitive research and education in the medical area has been started under the CCI framework programme.

The continued participation of the Cognitive Systems Group in the CEC research programmes on IT encompasses the following three projects commenced in 1992: KAVAS (Knowledge Acquisition, Visualization and Assessment System), COMIC (Computer-based Mechanisms of Interaction in Interaction in Cooperative Work) and GRACE (Graphical Communication in Human-Computer Interaction.

Since Jens Rasmussen retired from his post as a Research Council Professor at the end of 1991 he has continued his affiliation with the Cognitive Systems Group as a consultant. This arrangement has enabled the group to continue to benefit from Jens Rasmussen's rich scientific experience and knowledge from his many years of engagement with cognitive research and human-machine studies.

3.1 Computer-Supported Cooperative Work (CSCW)

The central issue addressed by the research in computer-supported cooperative work in the Cognitive Systems Group is the fact that cooperative work has an unavoidable aspect of distributed decision making and that this has radical implications for the design of computer-based systems for cooperative work settings.

This issue has been explored in an international working group entitled Designing CSCW Systems: Design Concepts for which Risø is the coordinator. The working group is part of a large collaborative network, »CoTech«, which comprises the majority of CSCW research activities in Europe, and is supported by a grant from Esprit Basic Research.

The thesis pursued by the working group has been that deficiencies of current CSCW systems can be attributed to untenable or simplistic notions of cooperative work on the part of the designers. In fact, the prevailing assumptions in CSCW research so far has been that cooperative work is carried out in small, well-defined, relatively stable, professionally homogeneous, and motivationally harmonious groups which can articulate their activities 'on the spot' - as 'teamwork'.

As established by a number of empirical investigations cooperative work in real work settings have substantially different characteristics: cooperative work involves large ensembles, typically whole enterprises or networks of enterprises within which there typically exist multiple layers of cooperative arrangements; such arrangements are normally diffuse and dynamic; cooperative work often involves activities of articulation with differing time horizons; cooperative work involves different professional specialists, work functions and perspectives, and is always subject to a noticeable element of conflict. Cooperative work thus involves distributed decision making, not only in the sense that activities are distributed in time and space, but also and most importantly that the different actors are relatively autonomous in terms of problem-solving strategies, conceptualizations, motives etc.

For the research in the group, the conclusion drawn from this is that CSCW systems must be designed in such a way that the underlying mechanisms of interaction are visible and accessible to the user in a format that fits his or her conceptual world and the user must be able to interpret, modify, adapt, circumvent or execute the mechanism of interaction in a given situation. This idea forms the basis of the project Computer-based Mechanisms of Interaction in Cooperative Work or **COMIC** that is supported by Esprit Basic Research. The COMIC project is pursuing the issue of mechanisms of interaction in empirical investigation, theoretical studies and experimental systems development.

Connected to COMIC, a number of research activities are exploring the articulation of distributed cooperative activities in real work settings with a view to developing CSCW systems.

The objective of the project Cooperative Design for Manufacture or **CODEM** - carried out within the CCI framework programme is to investigate distributed cooperative mediation and integration of information in design and process planning in manufacturing in order to specify requirements for a computer-based system to support the cooperative accomplishment of this mediation and integration.

This problem is also one of the central issues in the Computer Integrated Manufacturing (CIM) area insofar as a crucial element in CIM is to develop computer systems that can support the mediation and integration of different kinds of information from different production functions (design, process planning, production planning, production control, processing etc.). In recognition of the similarity of the issues addressed in the general CSCW research and the domain specific research within CIM, the CODEM project is organized as a collaborative project between CCI and the Institute of Manufacturing Engineering at the Technical University of Denmark.

Also closely connected to the COMIC project, the project Cooperative Management of Classification Schemes in Electronic Publishing (COMCEP) investigates distributed cooperative development and maintenance of classification schemes in common databases. An important activity is a number of field studies of cooperative handling of classification schemes in the context of production and distribution of tailor-made course material and technical documentation. The field studies are part of a Ph.D. project and carried out in collaboration with the Danish Technological Institute.

Publication in 1992: 57.

3.2 Information Technology in the Medical Domain

IT support in the medical domain draws increasing attention. The medical domain is characterised by high complexity, high risks, expert solving of complex problems under time limits, and ethical and cost constraints. The Cognitive Systems Group has initiated two projects in the medical domain in 1992. The KAVAS project is a three-year CEC-financed project, with CRI A/S, Denmark as the main contractor. The ANSIM simulator is the first step in the development of complex model of a patient's physiological reactions under anaesthesia, the work is carried out in close collaboration with RUC and Herlev Hospital.

In order to support the medical professional in his research and development of new medical procedures for treating patients, the KAVAS project has been initiated in collaboration with 12 European partners. The objective of the KAVAS project is to develop a prototype tool named KAVIAR. This tool combines knowledge acquisition from the medical research professional and from databases and example cases, with an integrated quality assurance mechanism. During 1992 we have had two tasks in this project: (1) modelling and characterisation of deep medical knowledge, and (2) performance of a work analysis of a department at a Danish hospital in order to develop recommendations on how the user-computer-interaction should be implemented. The knowledge-modelling task has been carried out in close collaboration with RUC. The work has concentrated on developing characterisations of deep medical knowledge in selected domains.

A selected medical domain, namely, a clinical chemical department, has been analysed to describe the prototypical tasks performed in the domain. The results will be used as input for the user-centred requirement of the KAVIAR User-Computer-Interaction. The focus in the analysis has been on the general characteristics of the work domain, the global functions, the prototypical tasks performed and the derived requirements for data processing. The preliminary observations indicate that the medical research domain involve numerous prototypical tasks, that the research tasks develop slowly and iteratively, that the amount of data is huge and that the typical medical researchers are novices in the use of advanced information technology.

The above-mentioned results combined with thosee from the other work packages of the KAVAS project are used as input for the specification of a general framework for the User-Computer-Interaction.

This framework includes the following:

- Recommendation for the overall user interface design,
- Conceptual design of the major visualisation objects and how the basic
- functionality for manipulating these objects should appear on the screen,
- Guidelines for the user interface design, regarding the actual users and the medical domain, and
- Guidelines and descriptions of how the overall handling of the system can be implemented.

The development of the UCI-framework started in 1992 and will continue through 1993.

In order to study human behaviour under the above-mentioned constraints, the ANSIM project has been initiated. Ethical consideration forbids experiments with live patients, so that studies of human behaviour must be carried out using a simulator. The medical domain dealing with anaesthesia has been selected, and the initials steps in simulating a patient during anaesthesia have been taken. Simulation of human responses to anaesthesia must be based on detailed mathematical models of pharmacokinetic and pharmacodynamic processes, circulatory system, respiratory system, transport systems of oxygen, carbon dioxide, inhalation, intravenous drugs etc. Essential parameters include pressure, flow rates and concentrations. Human responses are caused by the interaction among these systems. The final simulation will be based on an integrated model comprising these submodels. A computer model has been developed which displays the time history of different critical factors during an anaesthesia.

At a later time the model will be coupled to a patient mock-up and the different equipment in the operating theatre. Training of anaesthesia personnel as well as studies of their behaviour during a simulated accident can then be studied.

Publications in 1992: 39 and 40.

3.3 IT for Emergency Planning

ISEM: The aim of the ISEM project is to benefit from advanced information technology in coping with complex emergency situations.

ISEM began in 1989 and it is joint European project within the framework of CEC ESPRIT. The consortium is rather large and, apart from Risø, includes in its final phase four Danish, four Spanish and one Italian participant representing the European Community; furthermore, the consortium includes one Swedish and one Finnish participant representing the EFTA countries. Risø was the principal institution proposing this project and has been responsible for its management from an administrative as well as a professional point of view. The project was planned to last for three years but due to changes of partners it was prolonged by 10 months.

The needs of a system capable of coping with emergency situations have been analysed, specified and grouped into a set of functional modules as follows:

- Information exchange
- Situation assessment, on-site
- Situation assessment, off-site
- Extended preparedness plans (including what-if situations)
- Event and action log
- Training and drills

In order to be able to evaluate a generic decision support system, the system has to be implemented in well-defined applications, and two of these have been selected for this purpose:

- one within the nuclear domain, to be implemented at the premises of the nuclear end-user of the ISEM consortium, Tecnatom in Spain, and
- the other within the chemical domain, to be implemented at the premises of the chemical end-user of the consortium, Kommunekemi in Denmark.

During 1992 demos of both of these applications have been implemented, installed, tested and evaluated, and the demos have been approved by the experts appointed by the Commission in November 1992.

The hardware archetecture of the setups for the demos is shown in Figure 3.1. The organization involved in an emergency situation will normally consist of the on-site organization that is related to the plant at which the emergency situation takes place, and several off-site organizations, e.g. police, fire brigade, rescuing companies and hospitals. Each of these suborganizations will have access to the system via terminals installed on local area networks, LANs, and the various LANs will be able to communicate via X.400/X.25 protocol. Each LAN is equipped with a SUN database server, PCs prescribed for specific features, e.g. a Geographical Information System, GIS, and where needed, a direct access to the process control computer of the plant for which the emergency management system has been installed.

The ISEM project has by now produced eight official deliverables that have been approved by the Commission, and internal documents specifying in detail the results of the various phases of the project: the phase of analysis, specifications, design, implementation, installation, test, evaluation and validation.

The ISEM system is considered a step forward in relation to existing emergency management

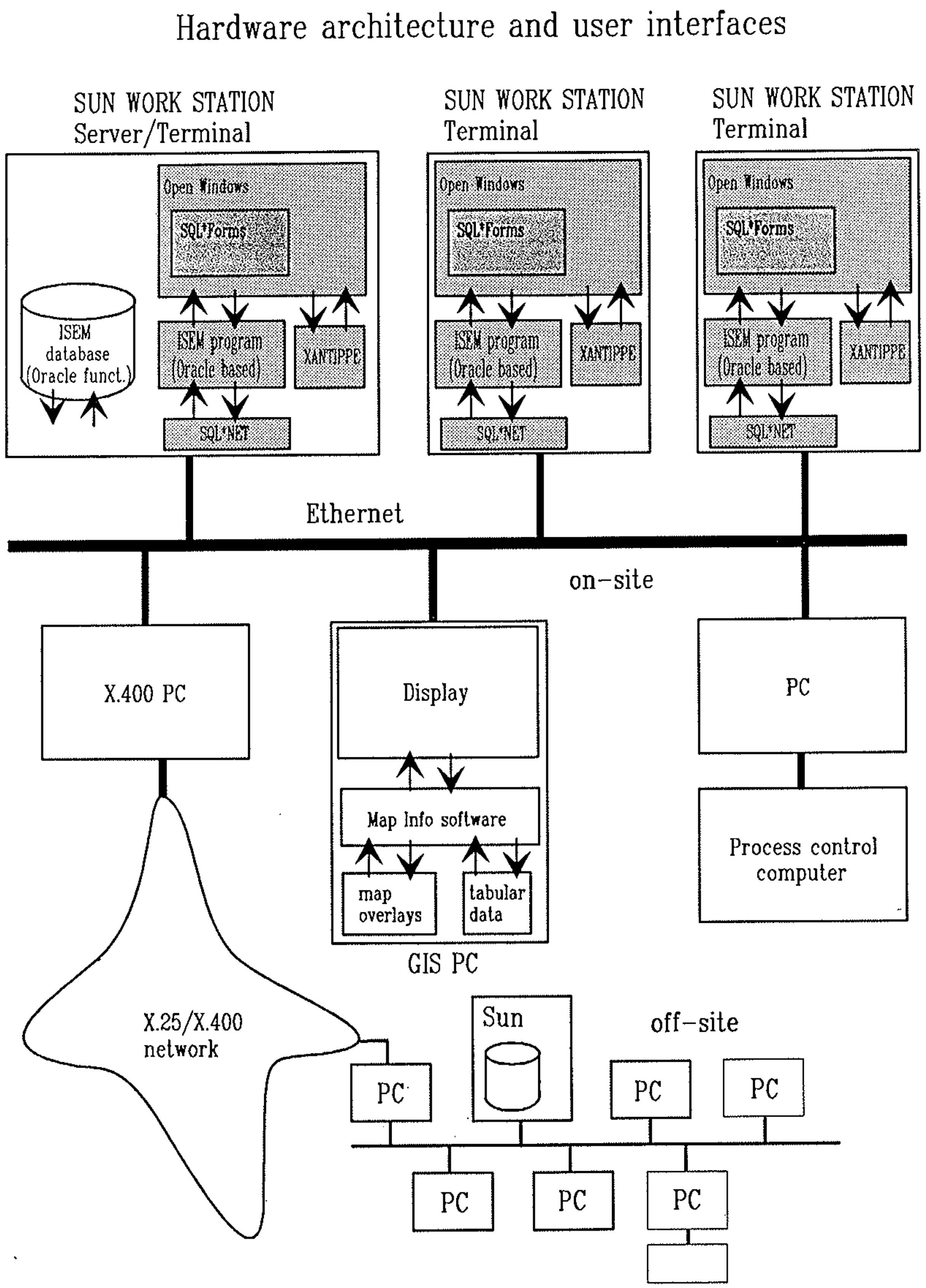


Figure 3.1. The ISEM hardware architecture.

systems normally based on paper documents. The computerised ISEM system offers the end-user:

- fast access to all the information needed to cope with a given emergency situation,
- reliable information not suffering from the dangerous situation of only partly updated documents, and
- direct access to various features, like an integrated information exchange system, situation assessment from GIS system having on-line connection to the database and an overview of the activities performed. In addition, it manages resources to offer the best possible background to enable it to benefit most effectively from these resources.

Consequently, the end-results of ISEM consist of the know-how obtained through the analysis and specification of end-user requirements, the know-how gained through the implementation, installation and test of the demonstration prototypes, and the ISEM toolbox offering the tools needed for creating a full-scale emergency management system based on specific customer requirements.

Message Management System (MMS): Within the ISEM project an electronic message management system dedicated to supporting communication among emergency management organizations was specified and developed by Risø. Prompted by favourable end user response, a separate effort, independent of the ISEM project, was undertaken in order to implement the MMS with major extensions and modifications of its user interface and functional characteristics.

This effort has resulted in two prototypes: in the first the MMS is illustrated as part of an integrated emergency management support system (for a chemical waste treatment plant). The prototype has been designed within a graphical user interface (GUI) environment largely as a mock-up in order to elicit more precise end-user requirements and in order to demonstrate how an integration of modules can support end-user requirements during both routine situations as well as critical situations. The second prototype is a fully functional and extended version of the MMS in the form of a stand-alone system, and similarly implemented in a modern GUI environment. The extended functions include possibilities of setting up machine- maintained folders of different types of task-related messages. At the same time, the MMS supports the creation of message forms (structured messages) to be used, for instance, in accordance with particular procedures and preparedness plans.

Mini-ISEM: The overall objective of the project is to ensure effective dissemination and exploitation of the results obtained in the ISEM project described above. The Mini-ISEM consortium consists of a Nordic subset of the ISEM consortium.

The project has been divided into two phases:

- a pre-phase - lasting for one year at most - including a market survey and specification of the exploitation plans. Based on the survey the areas in which an Emergency Management System seems to be most relevant will be unveiled in order to approach the potential market in the best possible way. Areas expected to be of interest are the nuclear and chemical industry, carrying trade, and environmentally related activities. Furthermore, the duration and activities to be included in the following phase will be specified in the pre-phase, based on the outcome of the analysis.
- a production phase in which final products will be developed for the market based on specific claims from the customer.

MUSTER: »Multi-User System for Training and Evaluation of Environmental Emergency Response« has been approved to receive financial support by the Commission within the Environment programme. The initialising of meetings and planning of the project have taken place during 1992, whereas the official start of the project, planned to run for two years, is scheduled for primo 1993. The consortium consists of 8 EC participants from Denmark, Italy and England, and one from Sweden representing the EFTA countries. The overall objective of the planned project is to develop advanced and efficient means of supporting **collaborative training** and **evaluation** directed to the special needs of environmental emergency management. This objective will be pursued by (1) establishing a set of methods or a **methodology** which will support both multi-user emergency management training as well as an evaluation of emergency management capability, and by (2) developing **specification of information technological systems support** matching the proposed training and evaluation methodology.

The final outcome of the project will be an illustrative SW prototype that will run on a commonly available HW platform.

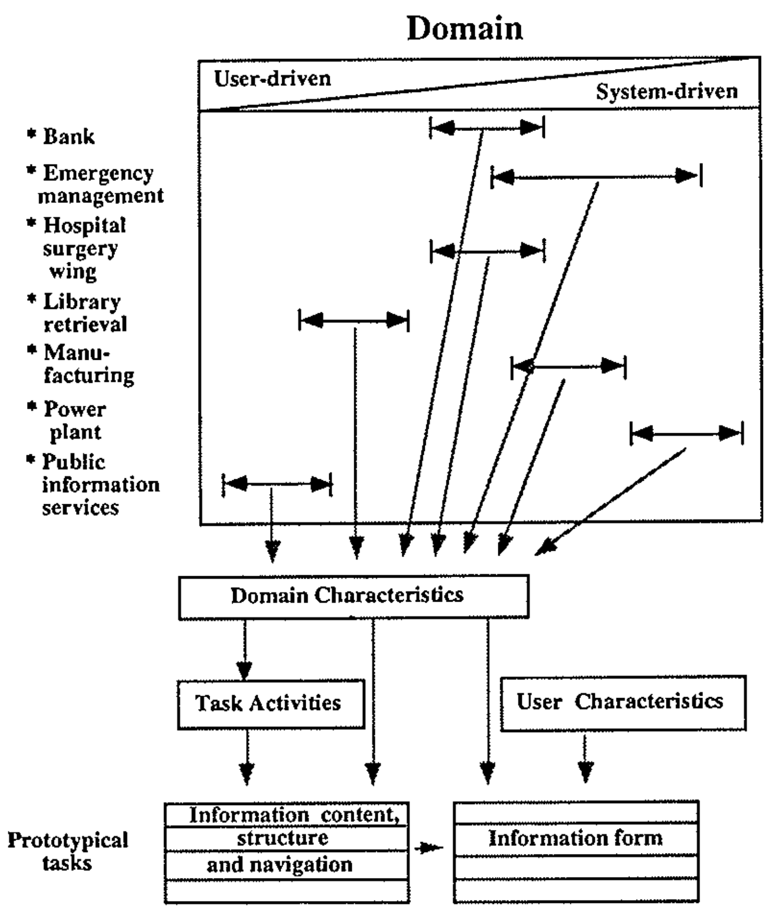
3.4 Interface Design Principles

Modern technology is evolving at such a rapid pace that the »target« to which traditional design support is directed is constantly on the move. With the advent of multimedia technology we have the ability to combine multiple known media and all known »modalities« of expression mediated by the computer (text, pictures, video, sound etc.). Seen in this light, a support in the present form of interface design guidelines appears to be too rigid. A more flexible and encompassing form of help is required, one that will allow designers to adapt to changes that are evolving in technology.

Most research on interface design in the disciplines of human computer interaction is based on empirical studies with emphasis on ergonomic and syntactical design issues. Ergonomic human factors studies can help in the design of interfaces that support the relevant low-level tasks (procedural tasks and perceptual/motor actions) of the human-computer interaction. But studies at this level cannot address the interface design problems pertaining to knowledge based tasks involving analytical problem solving. To develop principles for designing multimedia interfaces that support all kinds of tasks, work has been carried out on the development of a general framework or theory that comprises on the one hand analysis of the objectives and constraints of the domain, the task situation and user characteristics, and on the other hand users' interpretations of interface displays with special attention paid to semantic interpretations during analytical problem-solving tasks.

In 1992 three approaches have been initiated aiming at investigations of alternative ways of support in the design process and in the evaluation of interfaces in different domains and work situations. The three projects in which this work has been carried out are: (1) the MOHAWC project on *Design maps for ecological interfaces* on support to designers by substituting design guidelines with the development of »design maps«, (2) ecological interface designs studied in an analysis across domains of various interface displays, and in a specific example in the BESS project on *adaptive* ecological interfaces, (3) the GRACE project with focus on development of a theory of the cognitive significance of different choices of different combinations of *modalities* of communication in the computer interface (like natural language text and pictures).

Figure 3.2. Overview of display paths. Linking from a selected application through domain and activity characteristics to information content characterization together with a parallel linking form domain and user characteristics to info form characterizations.



Design Maps for Ecological Interfaces

The basic assumption in this type of design is that any attempt to formulate design guidelines should be based on a framework that will aid designers in analyzing the specific, deep structures in the domain. Ecological interfaces that make the deep structure of a work space visible are particularly effective for discretionary tasks in modern work systems: A map of the domain is a better guidance than route instructions, that is, work procedures. The complex cognitive coupling found in such systems has been analyzed as well as the importance of being able to support different levels of cognitive control and perception of the work domain at several levels of abstraction. Through analysis of a number of interface displays for different prototypical work domains-task situations -user characteristics a number of design maps have been developed. It is suggested in this work that rather than to try to guide the design process by guidelines and checklists, one should accept that »maps are better guides than route instructions«. That is, an attempt is made to support interface designers by maps of the various design territories instead of the usual guidelines. For this purpose, maps are suggested of (1) prototypical work situations, (2) knowledge representations used during design, and (3) display composition and interpretation. Further support of designers is suggested by the use of a catalogue of annotated interface formats, and samples of annotated designs are presented.

Adaptive Interface Design

Another set of ecological interface design problems not addressed so far has been raised in the BESS project (Book House Empirical Search Strategy). Project partners are Apple Computer A/S, the Danish Library Center A/S, the Ministry of Education, the University of Educational Studies, TIC (Center of Technology and Informatics), the Peder Lykke school amd the Academy of Royal Art. This project investigates principles for design of *adaptive interfaces* that evolve dynamically and make visible the deep semantic structure of a domain in different representations reflecting the expertise and preferences of users. Field studies in libraries have shown that based on frequent user needs, expert intermediaries have stored patterns of stereotypical user behaviour, which are used to associate book categories with features matching user stereotypes. In order to give the system the ability to model user characteristics and information needs, the system must have the similar potential for learning about individual users, i.e. to collect, analyze and store information about the domain and the user's preferences for certain contents and representations.

The Book House version developed for school libraries has therefore been expanded with a program for identifying patterns of user behaviour and for correlating these patterns with book content. These include three mechanisms: (1) the user modeling for characterization of users, (2) the matching mechanism for proposal of books fitting the user model and (3) the learning mechanism to improve and update the user stereotypes.

It is further planned to collect data from students using the Book House system in school libraries in order to identify frequent patterns of user behaviour to be implemented for later experimental evaluation of this type of interface support.

GRACE: A Theory for Interface Modalities

The basic assumption behind the GRACE project is that design guidelines should be based on a theory of the cognitive significance of different choices of interface representation, and they should include advice on the proper choice of combination of multimedia interface modalities for a support system, in particular with respect to users' interpretations at the level of semantics and the level of cognition.

One of the core problems of GRACE to be addressed is the characterization of the mapping between different types of information conveyed by an information system and the different modalities for expressing this information in the interface. The aim is therefore to develop general principles for conceptualizing this mapping and, if possible, devising a kind of taxonomy of interface modalities.

Similarly, there is no design theory to tell when to utilize specific combinations of modalities. It is not known when to use a conceptual diagram with textual comments to convey some given information, instead of a picture, an icon or a pure textual descriptions, nor what kind of cognitive and semantic properties of conceptual diagrams will make a good choice in some situations and a bad one in others.

Work has started on the problems of taxonomy development by building a database containing examples of graphical objects (but also including real multimedia examples like video sequences). This will be a point of departure for a systematic empirical study with the purpose of analyzing each of the examples and describing its particular properties in order to discover possible taxonomic structures, i.e. different types of graphical objects that can be distinguished by their semantic properties.

GRACE is an ESPRIT Basic Research project on running from 1992 to 1995. The participating partners are CCI, the University of Edinburgh, and IRST (Trento, Italy).

Publications in 1992: 41, 43, 44, 45 and 46.

3.5 Studies of Human Errors

The Group was involved in three studies in 1992 related to human errors and cognitive aspects of human performance in primarily safety critical work domains.

Ship navigation: This study concerned the validation of a maritime full-mission simulator at the Danish Maritime Institute which was used for navigator training and port design optimisation. Uncomplicated and safe manoevering during approach, berthing and departure is essential for efficient and acceptable operation of harbours. Training maritime navigators to perform difficult and possibly hazardous manoevres like tugging offshore rigs or entrances into unfamiliar harbours has been conducted for a number of years in the simulator evaluated in the project. Not until recently has it been possible to take the navigational and human aspects into realistic account in the design of harbours and ships. As a result, some ports are more difficult to call upon than necessary and, consequently, superfluously large protected areas have to be reserved for manoevering. Similarly, costly and excessive tug assistance is often required.

Data were collected to evaluate correspondence between the simulator and reality: (1) immediate, quantified feedback by navigators about the received realism of the simulator; (2) comparisons between performance in simulated and real tasks; (3) think-aloud protocols; (4) questionnaires; and (5) eye-mark recordings. The data revealed a set of complex problems to do with the relatively slow updating of the simulator's visual system.

While the overall objectives of the project were not directed at navigators' errors, results and experience from the study nevertheless provide an important empirical base for applying the influential framework of skill-, rule-, and knowledge-based performance and its related categories of human errors and adaptation mechanisms.

Performance by anaesthetists: This investigation involved a pilot study (the final phases of which will take place in 1993) carried out in collaboration with Herlev Hospital and Roskilde University aimed at analysing, on the basis of video recordings of real operations, the activities and procedures involved in general anaesthesia. The major focus of the study is on actions (and omissions) by physicians or nurses who administer anaesthesia to patients undergoing operations which might lead to a negative outcome for the patient. It is estimated that preventable human error is responsible for at least half of the serious anaesthesia-related mishaps (e.g. 2000-4000 annually in the United States alone). These mishaps typically result in major brain damage or death to the patient and therefore represent a serious problem.

The work of anaesthetists exemplifies a wide range of tasks of real-time process control found in other safety critical technical domains. The Group's involvement in this kind of study is therefore connected with its long-term work on human factors with regard to the safety and reliability of process control environments. At the same time, a sequel to the study is planned involving investigations of subjects' performance when using the ANSIM anaesthesia simulator.

The efforts so far have been directed at developing and testing a joint error analysis framework. Among the preliminary but tentative results are that a much greater part of the decision making during non-routine operations is more discretionary than might be expected and that experienced physicians' practices, judgments and »individual styles« vary considerably more than explicit and implicit procedures and rules would lead one to expect. At a more theoretical level, a major »negative« result has been that the classification of what actions (omissions) should count as human errors is highly dependent on the subject under study: experts allow themselves (and may safely do so) more leeway and deviations from normal procedures than novices or less-trained subjects do.

Communication failures: This study was led by Risø and carried out as a collaborative effort within the CCI. The data collection, which was recorded from a telephone hotline service, as well as a preliminary analysis were completed in 1992 but not the final analysis.

The study was undertaken in order to develop and test a classification of and hypotheses about the mechanisms involved in misunderstandings and other types of communication failures in work contexts. It should be added that hardly any systematic studies have been carried out of misunderstandings and other communication failures in modern technical (or any other) work contexts. The inspiration for the project derives from the Group's involvement in analysing requirements and designing communication and training support for emergency management. The latter efforts have not yet allowed a systematic study of communication in a technical work domain, hence the desirability of doing this study (a follow-up study of communication errors in emergency management is planned to start in the first half of 1993).

The data of the study consist of approximately 100 hours of audio-recorded dialogue on a telephone hotline service offered without charge to registered customers by a large software company. The entire material has been listened through, and about one-fifth has been subjected to repeated and close scrutiny; finally, from the latter about three-and-half hours of conversation (more than 20 dialogues) have been transcribed.

Results from the study indicate that »large« communication failures are typically induced in work contexts when people misinterpret each others' task-related goals and plans. A continuation of the study in the domain of emergency management is planned for 1993.

Publications in 1992: 2, 3 and 4.

4 Energy Systems Group

The activities in the Energy Systems Group (ESG) involve integrated energy, economic and environmental modelling and assessment of energy and environmental technologies. ESG conducts basic research on the analysis of energy systems with the aim of developing methods and models which are applied to a wide range of problems. The results are expressed in economic and environmental terms and used for energy planning by national governments and international organisations.

ESG undertakes studies of specific concepts, systems and technologies. The developments in energy and environmental technologies and the consequences for the energy system are closely watched, including the economic and environmental aspects of introducing these technologies in the energy system. The integration of energy and environmental questions in these assessments requires that new information of environmental impacts of different technologies be evaluated in relation to their use in the energy models.

In collaboration with UNEP Collaboration Centre on Energy and Environment (UCC), ESG carry out studies of the cost of reducing greenhouse gas emissions for Zimbabwe and Denmark. UCC has formulated guidelines for establishing cost curves for reducing greenhouse gases, and in the studies in each country the guidelines are tested. The cost curves show the cost of reducing emissions in order of precedence to the cost of the various possible options for implementing the reductions.

For the Nordic Council of Ministers a study was made of the trade-off between investment in electricity production facilities and electricity savings among the consumers. The study shows that the investments in decentralized natural gas-loaded turbines will suffer from the savings; this is because conventional production capacities will be more effeciently utilized in the case of savings.

For the utilities and the Danish Energy Agency ESG carried out a study of the possibilities and consequences of introducing hydrogen in the energy system. The study shows that hydrogen is realistic as an energy carrier in the future system on condition that environmental considerations are given high priority and that hydrogen is used in the transport sector.

To evaluate the economics of activities in Danish subsoil, ESG is building a new cash-flow model MOKKA for the Danish Energy Agency. The model gives the year-by-year investment, production, tax deductions and tax payments. Priority is given to the user interface of the model and the possibilities for user control.

A comparative energy and environmental study has been underway, focusing on the relationship in the Nordic and Baltic regions between energy consumption and acid emissions, CO_2 emissions and use of exhaustible resources. The environment scenario of the study shows that energy consumption and CO_2 emissions remain relatively constant up to year 2010, while an average reduction in acid deposition of 30% is achieved for the area as a whole. This result must be seen in the light of the sensitivity of large areas in the Nordic countries to acidification, and that critical load values are exceeded many times in Poland, Estonia, Latvia and Lithuania.

As part of the CEC CORINE programme a special methodology for establishing emission inventories has been developed (CORINAIR). The CORINAIR methodology has been extended in the number of participating countries, from the 12 EC-countries to 25. The number of pollutants and sources included in the emissions inventory are also extended. In 1992 ESG was the host of a workshop with the purpose of introducing participants from the other Nordic countries and the Baltic states to the CORINAIR method.

In the field of renewable energy ESG is undertaking a study of accommodating wind energy on a larger scale within the energy system, continued the planning of wind energy utilisation in Egypt, participated in a study of maximising the share of wind energy in the electricity supply of Cape Verde and in late 1992 participated in a evaluation of the Norwegian wind energy research programme.

4.1 Greenhouse Costing Studies

The UNEP Greenhouse Gas Abatement Costing Study was initiated in the autumn of 1991 (see section 5.2). The project aims to clarify some economic issues involved in greenhouse gas limitations by carrying out a number of country studies on a comparable basis. These studies will then contribute to the establishment of a consistent methodological framework for undertaking cost assessments of greenhouse gas abatement.

The project is divided into two phases. The first consists of detailed studies of the underlying issues in estimating abatement cost, including analyses of modelling options and reviews of existing cost estimates, and a small set of national studies. These country studies aim at establishing the current status of analysis and data in the countries concerned and draw lessons from past experience; they illustrate in depth the practical issues raised in embarking upon abatement cost studies in widely diverse countries. Drawing on this experience, phase 1 of the project forms the basis for establishing a consistent and iterative approach to national abatement cost studies. The second phase of the UNEP Project will then test and enhance the methodology through a series of national studies which apply and adapt the approach to specific national conditions.

The Energy Systems Group is involved in the preparation of two of these country studies: Denmark and Zimbabwe.

The phase 1 study has been completed for **Denmark**. The study comprises two parts: part one summarises the country background including energy demand and supply, emissions and current energy policy issues; part two reviews existing studies of CO_2 reductions for Denmark. These include the Danish Government plans: Energy 2000 and the plan of action for the the transport sector. Furthermore, studies are reviewed which were undertaken by the Technical University of Denmark and the CEC.

The main findings of phase 1 indicate that there is significant agreement between results in spite of differences in methodology, technology evaluation and general assumptions. In general, analyses agree on a 15-30% reduction potential for CO_2 emissions by 2005 or 2010 with no additional costs to society. However, none of the studies considers implementation costs of necessary policy measures, or possible hidden costs.

Likewise, no-regret options identified by different studies coincide. These options include an increased use of CHP, electricity conservation in households and services and energy conservation in industry. This indicates that the results obtained are fairly robust despite differences in methodology and assumptions.

Phase 2 concentrates on generating the actual CO_2-reduction cost curve. Some of the methodological considerations for phase 2 have begun in 1992.

The reduction cost curve relates the quantity of CO_2 reduced by a specific technological or political option to the associated costs of implementing these options. The cost curve may be defined as:

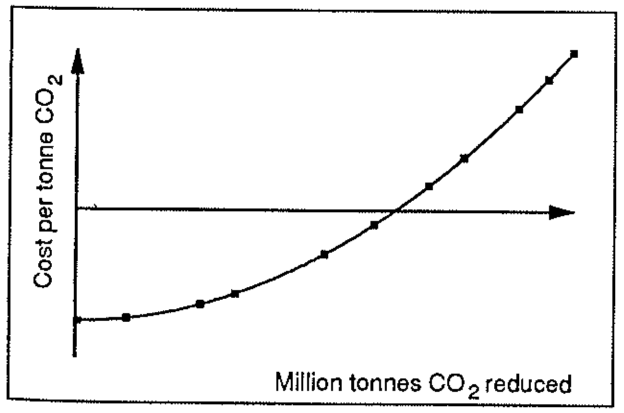
> a ranking of the annual costs of specific technologies for reducing the emissions of CO_2 by a specified annual quantity. The costs include the annual fuel and O&M costs and investment cost levelized by a given discount rate over the lifetime of the project. Costs are calculated in real terms.

Figure 4.1 shows a continuous version of the cost curves. By necessity, the specific technological options are the starting points for the generation of the CO_2-reduction cost curves. There are several possible ways to establish a cost curve:

a) The partial solution. Each technology option is evaluated separately with respect to both incurred costs and CO_2 emissions. Results are compared project-by-project with a reference project and ranked to give a stepwise cost curve. The procedure is little more than a stacking of abatement options, where the ranking of the options is done separately for each, ignoring interdependence among the options. The cost curve is built up of partial independent segments. The solution is simple, but theoretically not entirely satisfactory.

b) The retrospective systems approach. Compared with the partial solution, this approach has the advantage of taking into account the interdependence between the given project and every other previous project on the cost curve. A drawback is that once a project is included, this project is independent of less valuable projects, although a dependence might exist. This approach requires the development of a reference case with which to compare the abatement projects. Furthermore, it is important to notice that the retrospective method implies that once an abatement option is included in a scenario, it will be a permanent part of all subsequent scenarios.

Figure 4.1. Continuous cost curve.



(c) The integrated systems approach. This approach requires the existence of a well-defined reference case, and a fully developed energy systems model. It takes into account all the interdependencies within the system (as represented by the energy systems model). However, which technologies to choose will not be as clearly defined by the cost curve. The curve will be continuous (as shown in Figure 4.1) and each point on the curve will represent a basket of technologies used.

The aim of the Danish project is to establish the cost curve following the integrated system approach. This will be done using the BRUS-model, a long-term simulation model developed to handle the scenario-calculations for the latest Danish energy plan, Energy 2000.

The phase one study for **Zimbabwe** follows the same line as for Denmark. An overview of the energy system in Zimbabwe constitutes part one of the study. In Zimbabwe traditional biomass fuel accounts for about 50% of the total energy supply and 96% of total rural household energy consumption. The coal reserves are substantial amounting to 2-10 billion tonnes. Coal supplies most of the commercial energy demand, particularly in industry where process energy depends on coal and electricity almost completely. Coal is also increasingly becoming the base fuel for electricity generation in supplying more than half of domestically generated electricity. The rest comes from hydropower and imports.

The second part was a critical evaluation of a CO_2 reduction study financed by the United Kingdom Overseas Development Administration.

The establishment of the cost curve for a developing country like Zimbabwe creates special methodological problems. The construction of a base case by the »business as usual« methodology used in developed countries is not feasible here, so a more goal-oriented method will be used in phase two, incorporating the expected changes on the economic structure in Zimbabwe. An analytical model for intercountry conversion of industrial energy intensities is being developed. A special study to investigate the CO_2 source/sink character of the biomass sector has been started as an extension of the project.

A list of options for reducing the emissions of CO_2 has been established. Preliminary indications from the study are that significant opportunities exist for implementing the options. Some of the barriers to this are lack of information on abatement possibilities and lack of capital for the necessary investments, and reluctance to give up the use of the abundant local coal resource. The Zimbabwean study has highlighted the need to enhance local capacity for analysing and assessing posible abatement options and their impacts.

Publications in 1992: 34 and 36.

4.2 Electricity Production Versus Electricity Conservation

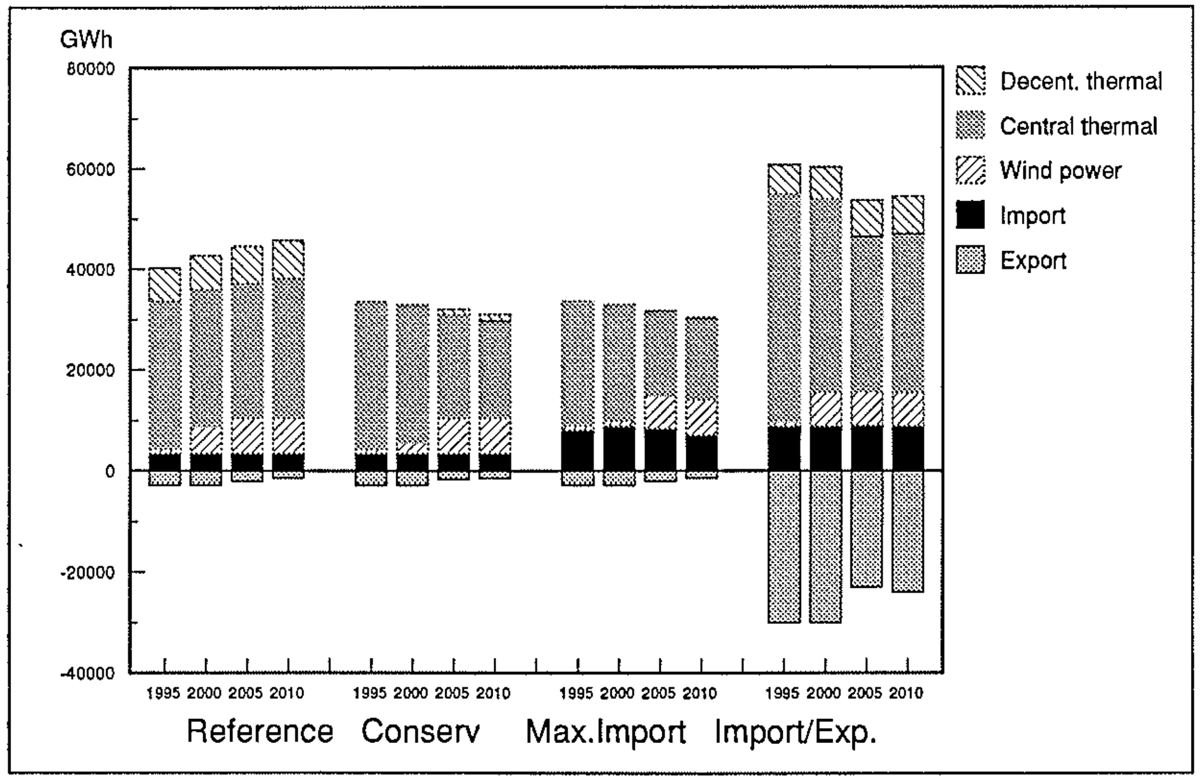
Utilization of the most effective technology in all the demand sectors by 2010 would reduce the electricity demand in each of the Nordic countries by about one-third. In all the countries the potential for electricity conservation is largest in the commercial sector. The consequences of realizing these potentials in the various Nordic countries will be very different from country to country, because of the different structures of the electricity systems. This is a result of a study financed under the energy research programme of the Nordic Council of Ministers. It was completed in 1992 and the report will be published early in 1993.

In countries that have an electricity system based on thermal power generation that is subject to strict limitations on the emissions of SO_2, NO_x and CO^2, e.g. Finland and Denmark, electricity conservation will not only reduce the need for new generating capacity. Further, it will also reduce the need for pollution abatement technologies that would be necessary to fulfil the emission reduction requirements. For Denmark, this would also mean that fewer local combined heat and power plants would have to be built.

If the electricity system is significantly hydro based, as in Norway and Iceland, electricity conservation means that there would be a larger potential for electricity export or more electricity available for power-intensive industries. The transmission capacity and the organization of the international electricity trade will be the limiting factors for the economic and environmental advantages of electricity conservation.

A modelling concept was developed in the project to quantify the potentials for electricity conservation and its consequences for the national electricity systems. The supply and demand sides were modelled differently to take into account the very different priorities required by utilities and consumers.

Figure 4.2. Structure of the electricity generation system. Denmark.



The demand side has been based on estimates of the potential of economically viable conservation measures in various sectors, which were compared with selected electricity demand forecasts in each of the Nordic countries.

On the supply side is an optimization model based on a network description of energy flows and systems constraints. This model is developed from the Danish version of the EFOM Model for the study on a »CO_2 Constrained Policy« of the CEC; the model consists of a database describing the energy flow network with techno-economic data from the BRUS Model and a set of infrastructure data and demand forecast data for each country. The optimization is made by linear programming that minimizes discounted total costs. Figure 4.2 shows a series of model results for the structure of a fossil fuel-based electricity system. In the »Reference« case there are no conservation measures; »Conserv« contains all the conservation measures. In »Max. import« the electricity imports from hydro-based systems is increased, and in »Import/Export« the limitations on export to systems based on coal condensing power plants have been removed.

Publications in 1992: 20.

4.3 Hydrogen as an Energy Carrier

In Denmark the utilization of hydrogen as an energy carrier has been considered in the project titled 'Hydrogen as an energy carrier'. The project has been financed by the Danish Ministry of Energy and by the Danish electric utilities ELSAM and ELKRAFT. The purpose of the project has been to investigate the possibilities for introducing hydrogen as an energy carrier in the future energy system of Denmark, and to point out the economic and environmental consequences. By introducing hydrogen it may be possible to incorporate a larger amount of renewable energy in the energy system.

A large part of the Danish energy system consists today of combined heat and power plants and an expansion of CHP in the future may result in heat or electricity storage problems. Hydrogen could become an efficient means of electricity storage.

The perspectives for utilizing hydrogen as an energy carrier in the future depend strongly on the expectations to the energy sources and how the energy system will operate. In order to illustrate how hydrogen may enter as an energy carrier in the energy system, existing data on electricity production and means of supply from the electricity plants have been used as basis. In this way the perspectives for utilizing hydrogen as an energy carrier in the Danish energy system have been assessed as realistically as possible.

In order to define different scenarios for hydrogen the whole hydrogen cycle from production to transportation to storage and utilization of hydrogen has been considered. The most relevant technologies for the Danish energy system have been pointed out and used in the different hydrogen scenarios.

Electrolysis, coal gasification and biomass gasification have been pointed out as interesting options for producing hydrogen in the Danish energy system. Most important possibilities for utilising hydrogen in Denmark are fuel cells placed in central plants or hydrogen as fuel in the transportation sector. Hydrogen is supposed to be stored in large underground caverns and distributed through the natural gas network.

The safety aspects of utilizing different hydrogen technologies in the energy system have been assessed, and these have been taken into account in establishing realistic total scenarios.

The different scenarios have been calculated in a model system which has been developed in the project. It consists of two submodels. The first simulates the operation of the energy system by introducing different hydrogen technologies, while the second assesses the consequences from a technical, economic and environmental point of view by introducing the different hydrogen technologies in the Danish energy system.

3 types of total scenarios have been calculated:

- A scenario describing the electricity system in which hydrogen is introduced as a possibility for storing electricity.
- A scenario describing the production of hydrogen where the electricity system is assumed to function as a producer of hydrogen to be utilized as fuel in the transportation sector.
- A scenario describing environmental impacts. Here hydrogen is introduced in the energy system in order to reduce the emissions of carbon dioxide.

The main conclusion of the project is that hydrogen seems to be a realistic energy carrier in the energy system. From an environmental point of view the introduction of hydrogen in interplay with renewable energy technologies will be attractive utilizing hydrogen in the electricity and transportation sectors, since the total CO_2 emissions from the energy system will be reduced significantly.

4.4 Oil and Gas Cash Flow Model

Risø's engagement in the technical-economic modelling of the offshore sector was started in 1986 when a detailed description of the economic aspects of the legislation concerning exploration and production of hydrocarbons was worked out. This description was used as the basis for incorporating the Danish legislation in a Norwegian cash-flow model, MECCA, which was introduced in the Danish Energy Agency (DEA).

However, due to the shortcomings of the MECCA model, DEA now seeks a successor to this model. Therefore, Risø is developing a completely new cash-flow model, MOKKA, for the individual oil and gas fields as well as for the companies operating in the Danish offshore sector.

MOKKA covers a wide area of analysis concerning economic aspects of the offshore sector. Further, it serves as a database and may be coupled to other databases. It is designed to model alternative projects for comparison, and may also be used to analyze the results of changed taxation rules.

MOKKA is being developed together with DEA. The user requirements considering the main facilities were specified. Examples of such facilities are input facilities, reporting facilities (tables and graphics) and facilities for controlling the operation of the model. Also in close contact with DEA the data handled by the model are described. This covers input data given by the user and data calculated by MOKKA.

The database for input data and calculated data are designed and established. Menus and forms for input data and for output reports are designed and programmed.

First of all, the algorithms are based on the above-mentioned description of the legislation concerning exploration and production of hydrocarbons. In addition to the strict rules of the legislation, the common practice of expounding the more doubtful parts of the law texts is modelled. Moreover, the model will comprise algorithms simulating the decisions made by the management of an oil company regarding, for instance, depreciation. All relevant expenditures (exploration, investments, operation costs, transport costs, abandonment costs) and income (the value of the produced hydrocarbons) are modelled. Among the values calculated are depreciation, tax payments (corporate tax and hydrocarbon tax) and royalties.

A generator for reports (tables and graphical output) is being developed and various facilities for 'compound' calculations will be defined and programmed. As an example of such facilities could be mentioned an automatic comparison of two scenarios which differ in only one way, namely, whether a particular oil field is developed or not. Another example is a facility that shows how some key calculated data depend on some key input data (sensitivity analysis).

The model may compute the production value, net income, deductions, taxes paid and so on, all on a yearly basis from given data.

In the development of the model, emphasis is put on a good user interface both for controlling the model by means of a menu system, and for input of data. Considering report facilities in MOKKA, the user can define his own tables and plots. MOKKA is running on VAX/VMS computers. The model is developed and runs within the Smartstar system. The design module of Smartstar is a 4. generation tool that facilitates a fast development of screen displays for input of data and for creating connections between these screen displays and the database used. Other parts of MOKKA are programmed in Fortran.

Publications in 1992:

4.5 Environmental Consequences of Energy Planning in the Nordic and Baltic Regions

The Nordic and Baltic regions could be recognized as a social and economic entity where it may be economically beneficial to cooperate on energy and environmental planning. This is especially the case in relation to air pollutants such as acidic emissions and CO_2 emissions.

An analysis has been carried out on the effects of transferring technical and economic resources between the various countries in order to achieve efficient environmental improvements. The main source has been the official energy- and environmental plans for the area. In order to go into more detail on the CO_2 emission problem a special economic model has been constructed for the Nordic countries which allows for a consistent investigation of the macroeconomic effects of a far-going emission reduction policy.

The two projects have been financed by the Nordic Council of Ministers.

As a starting point a broader analysis was carried out focusing on the relationship between energy consumption in the Nordic and Baltic regions and the resulting environmental impacts regarding:

- acid emissions as SO_2 and NO_x
- CO_2 emissions
- use of exhaustable resources

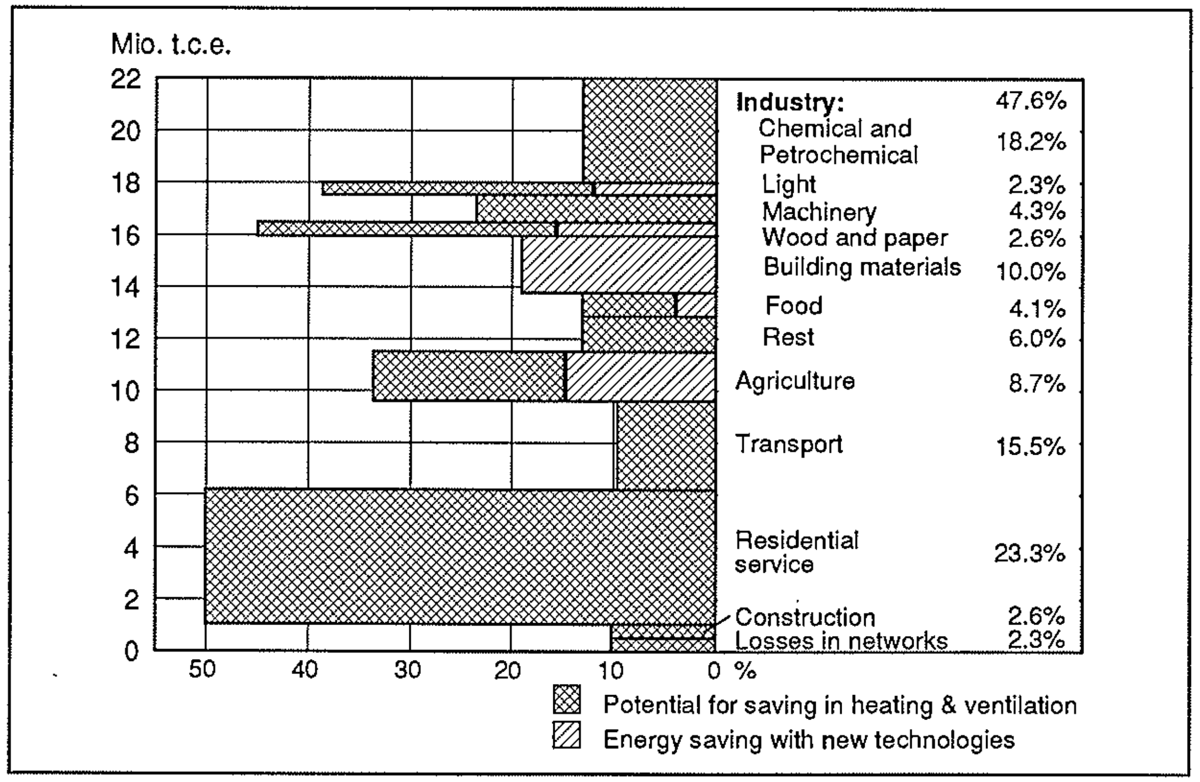
The analysis contains a database for Denmark, Finland, Norway, Sweden, Estonia, Latvia, Lithuania and Poland with the following data:

- gross energy consumption divided into fuel and consumption sectors
- emissions of sulphur (SO_2), nitrogen (NO_x) and carbon dioxide (CO_2)
- land area, population size, heated building area, average number of degree days and industrial energy consumption
- five different scenarios for each country covering the period 1990 to 2010 comprising a reference scenario and four environment scenarios

The main source of information has been national official energy plans and statistics, which have been modified and transformed into comparable measures. The RAINS model has been used for calculating the relations between country emissions and critical loads.

The scenarios have been utilized as a basis for representing three indicators which in combination reflect the goal of sustainability. The indicators are fossil fuel equivalent, exceedance of critical load and carbon dioxide emissions. The indicators may be used by policy makers in identify-

Figure 4.3. Potential for energy savings in the Lithuanian energy system



ing aspects of sound environmental strategies in energy planning.

Results of the analysis show that energy consumption and CO_2 emissions remain relatively constant in the environment scenario compared with a 16% increase in CO_2 emissions in the reference scenario. Concerning the acid deposition, a 30% reduction is achieved in the environment scenario instead of a 20% decrease found in the reference scenario. This result must be seen in the light that the Nordic region (especially Norway, Finland and Sweden) constitutes a highly sensitive region regarding acidification, and that critical load values are exceeded many times in Poland, Estonia, Latvia and Lithuania.

Single country initiatives applied alone in the Nordic countries do not result in considerable achievements in lower exceedances of critical load values in the region. The Nordic countries have already utilized a great deal of their potential for reducing acid emissions, so the difference between the reference scenario and other scenarios does not vary significantly when applying, for example, flue gas control. Furthermore, a study of the source-receptor relations in Europe show that the Nordic countries receive a considerable proportion of total deposition from countries outside their region.

The application of the flue gas control scenario in both the Baltic and the Nordic regions did not show considerable improvements in achieving critical load values compared with reductions in the Baltic region alone. A conclusion on energy planning in this region is that abatement strategies applied in the Nordic countries will not cut down significantly on exceedances of critical loads. This can be achieved only by joint international efforts.

With the purpose of carrying out a more detailed analysis of the long-term impact of international greenhouse agreements on the economies in the Nordic countries, an economic growth model was developed. The model is a general equilibrium model and is suited for analysis of a 50-100 years time horizon. A main source of inspiration was the Global 2100 model developed by Manne and Richels (US EPRI, 1992).

The economic growth model contains two separate submodels, namely an energy system model and a macroeconomic model. The energy system is described by a stylized »bottom up« model containing 9 electricity generation technologies and 9 non-electric energy supplies. This model is linked to a one-good-macroeconomic growth model through the supplies and demands of energy. The model is therefore an integration of the »bottom up« and the »top down« approaches.

The model differs from the Global 2100 model which uses a non linear optimization principle. The markets are »decentralized«, i.e., the model attempts to describe the actual functioning of the economy and it facilitates more flexible analyses.

Publications in 1992: 15 and 16.

4.6 Emission Inventories

Work continued in 1992 on the CORINAIR-90 emission inventory to both CEC and The Economic Commission for Europe/UN. The inventory has been significantly expanded, covering now 25 countries, well beyond the original 12. The number of pollutants has also been increased and the inventory now covers NO_x, SO_2, CO_2, CH_4, NMVOC, CO, N_2O and NH_3. The goal of the CORINAIR project is to create an inventory with the following attributes: completeness, consistency and transparency.

Completeness is achieved by including all known sources of the pollutants in question. The distinction between anthropogenic and natural sources is thereby avoided. In our part of the world almost all nature has been influenced by man for centuries and any distinction is a matter of definition. For the first time emissions are included from maritime sources: shipping, fisheries, harbours and offshore activities. But it was decided that international shipping, that is shipping between two ports in different countries and transit shipping through national waters without entering port, should not be included in the national totals which are subject to reductions according to the convention on transboundary air pollution. For air traffic only landing and take-off is included in national totals. It was decided that air-traffic above 1000 m and international shipping should be inventoried collectively.

Many emissions originate from the consumption of fuels. In the 1985 version of CORINAIR four fuels were distinguished. In the new CORINAIR-90, 45 different fuels for Europe are defined but not all are used in Denmark.

Consistency is accomplished by using a common set of activities (anthropogenic and natural) which emit pollutants. The emission factors used both for area and point sources should represent the technological level in the country. In order to

achieve consistent reporting from all countries on the implementation of the CEC directive 88/609 on Large Combustion Plants, it was decided to incorporate this very detailed reporting into the CORINAIR-90 inventory. Close cooperation with the Danish power plants has been established in order to meet the requirements. The COPERT model for calculating emissions from road traffic covers now all the mentioned pollutants and has been expanded to cover off-road combustion engines as well, such as tractors, bulldozers, forklifts and lawn mowers. Emission factors for such equipment are not well-known, but the computation shows that the emissions from off-roaders are of the same size as those from trucks. As these emissions have not been previously calculated it will be necessary to recalculate the values from previous years.

Transparency is required in order to make international comparisons valid, and to enable a constructive exchange of knowledge on the detailed level. In CORINAIR this is achieved by entering the information on which emissions are calculated instead of the bare emissions.

ESG has over the years participated in the development of the CORINAIR methodology and is responsible for the Danish implementation.

Ideally the CORINAIR inventory should be made bottom-up. As far as possible this is in fact the case, but in many fields information is insufficient and the activity levels must be taken from official statistics. These statistics are in general grouped according to economic sectors each of which contains several different technologies with different emissions. For the purpose of modelling the transport of emissions, the large point sources are placed geographically and all smaller sources are allocated to counties as area sources. In those cases where only national figures are available, a number of models are used to make the split. It is planned to allocate road traffic emissions and emissions from ships to lines that overlap the area sources. By means of the geographical information system ARC INFO emissions can then be added and computed for any grid system required for modelling chemistry or air movement.

In 1992 the three Baltic Republics Estonia, Latvia and Lithuania were visited on behalf of CEC/DG XI and agreements were made with their governments concerning their participation in CORINAIR-90. ESG will be project leader for the three countries. In March a CORINAIR Training Course was arranged at Risø for experts from the Baltic and Nordic countries.

Publications in 1992: 6 and 53.

4.7 Renewable Energy Sources

Over the years ESG has undertaken a number of studies within the field of renewable energy. During 1992 the activities has been concentrated on wind energy in the following projects:

Wind energy planning in Arab Republic of Egypt. As a result of the findings in an early 1990 feasibility study, a project was formulated for demonstration and development of technology and planning in the wind energy sector in the Arab Republic of Egypt. An immediate action programme was already in operation in 1990-91 and in 1992 the main project was put in operation. During 1992 representatives from the different ministries, local authorities and institutions who are to participate in the planning of the wind energy sector have been nominated, and a seminar for the participants has been planned.

The planning is executed as part of a major project and in collaboration with the Department of Meteorology and Wind Energy. ESG makes a contribution to the planning as institutional support to the New and Renewable Energy Authority, through the knowledge and experience of energy planning and energy economics. Furthermore, a scenario model for planning the wind energy sector was initiated in late 1992.

Feasibility study of wind farms, Cape Verde. During October 1992 ESG together with the Department of Meteorology and Wind Energy participated in a mission to Cape Verde with the purpose of examining the maximum possibilities for wind-generated electricity in the electrical networks. As wind conditions in the area are very good wind turbines are therefore an obvious supply to be exploited. Cape Verde faces an increasing demand for electricity, not only due to growth in economic activities and population, but also to a rising need for power for desalination plants. Today's technology for generating electricity consumes fuel resulting in high prices. Altogether wind turbines have become an attractive and economical alternative for electricity production.

Late 1992 ESG together with the Department of Meteorology and Wind Energy participated in an **evaluation of the Norwegian wind energy research programme.** The evaluation was requested from »Norges vassdrags- og energiverk« (NVE). It comprised the goals and projects of the programme and an evaluation of the relevance and possibilities for a continuation of the programme. An evaluation of the possibilities of the future utilization of wind energy and recommendations for programme content are also given.

Large-scale application of renewable energy technologies. In collaboration with the Danish utility companies ELSAM and ELKRAFT a project on the long-term introduction of renewable energy technologies in the energy system was started in 1992. The aim of the project is to study the consequences for the electricity system of a large-scale application of wind and other renewables.

Within the project a number of strategies concerning the introduction of renewable technologies are developed, with main emphasis on the use of biomass, windpower and solar energy. A »business as usual« scenario is developed including the consequences of these different strategies with regard to:

- the operation of the electricity system in the short and long-term,
- the configuration of the energy system, including the need for conventional capacity, and
- the economic, energy and environmental impact.

Finally, a number of different scenarios for society at large are developed to test the robustness of the energy system strategies.

At present most of the work concerning the definition of scenarios for society has been carried out. A number of working groups are set up to handle data collection, analysis of the operation of the energy system, and the necessary development of simulation and energy systems models. The project will continue throughout 1993 to be finalized mid-1994.

5 UNEP Collaborating Centre on Energy and Environment

The first two years of the Centre's existence have been characterized by expansion of activities and consolidation. In 1992 the three organizations which are responsible for supporting the Centre agreed to finance a further two year period with core funding, including an expansion of personnel. The three organizations are the United Nations Environment Programme (UNEP), the Danish International Development Agency (Danida) and Risø.

The work of the Centre continues, to be directed within an overall mandate to promote the incorporation of environmental considerations in energy policy and planning, especially in developing countries. The specific activities of the Centre fall into four categories:

Assessment of environmental impacts from energy production and use,

Energy-environment policy studies in selected countries,

Information centre on energy-related environmental effects, energy planning methods and models, and

Scientific and technical support to UNEP on energy questions on an *ad hoc* basis.

The main activity within the category on environmental impact analysis is the collaboration with the Stockholm Environment Institute's Boston office on the UNEP/SEI Environmental Database (EDB).

The Centre plays a dual role in the area of energy-environment policy and planning. Assistance is provided to UNEP in establishing projects in some of the larger developing countries, while the Centre also participates directly in such activities at national and regional level.

Work started on the first UNEP national policy project in India at the beginning of 1992. The Tata Energy Research Institute of New Delhi was the main implementing organization. An interministerial steering group chaired by the Indian Ministry of Environment and Forests governs the project. The role of the Centre is to monitor the activities within the project and to provide technical support where required.

A number of direct collaborative activities were undertaken in 1992. Among these the dominant one was with the African Energy Policy and Research Network (AFREPREN) and the Foundation for Woodstove Dissemination (FWD) on Environmentally Sound Energy Options for Africa. This collaboration included arrangement and participation in a meeting of African energy experts in Nairobi in May, the proceedings from which were co-edited by the Centre and will be issued in book form early in 1993.

Support to UNEP's Energy Office remains an important activity for the Centre. While such support is often supplied on an ad hoc basis, it has also included the preparation of papers and statements on special topics, and direct support at the Nairobi headquarters. A consequence of the consolidation of the Centre's role within UNEP is that support is provided to several different parts of the programme, both in headquarters and in the regional offices. For example the activity associated with the Global Environment Facility (GEF) has at times been quite significant. This has had the added benefit of strengthening links to UNDP and the World Bank.

The major activity in the Centre outside the core funding has been the project on national greenhouse gas abatement costing, which is financed by UNEP's Climate Office. The first phase of this project was completed in mid-1992 and was marked by a workshop at Risø followed by publication of a report containing reviews, discussion of methodological issues, and description of studies in the four countries initially involved in the project. Additional UNEP funding, along with support from the Finnish and French governments, has made it possible to include country teams from Brazil, Egypt, France, Senegal and Thailand. In addition, the government of Venezuela is joining the collaboration using its own resources, and the Stockholm Environment Institute's Boston office will contribute with a study of the USA. The second phase of the project is scheduled for completion in June 1993.

Environment and development became almost household terms during 1992 with the international attention surrounding the United Nations Conference on Environment and Development which was held in Rio de Janeiro in June. Although energy did not feature explicitly on the agenda of the conference, it was nevertheless an important issue, not least because of the links to the greenhouse effect and climate change.

UCC staff members were involved at various levels in the preparation of direct inputs. For example the statement from the African energy experts meeting was distributed at UNCED by the FWD Executive Secretary who later in the year worked as guest researcher at the Centre.

5.1 Planning and Policy Studies

The increasing evidence of environmental deterioration related to energy production and consumption has led to serious concern in many developing countries. A general recognition is emerging of the need to adjust development objectives to the capacity of the environment to assimilate the negative impacts from energy activities. Such recognition is a response not only to international attention but also, and even more importantly, to the necessity of sustaining the natural resource base of the nations.

The challenge for energy planners and policy makers in the 1990s is to identify ways of incorporating the environmental dimension into the planning process. This places heavy demands on planning methodologies, institutional capacities, the availability of data and knowledge of energy-environment interactions.

In response to these demands and in line with its objectives, the Centre has established, as one of its priorities, the formulation and policy guidelines for incorporating environmental considerations into energy policy. This includes the development of energy-environment planning concepts adapted to the developing country context, the establishment of environmental databases, and the enhancement of local capabilities for analyzing energy-environment issues. These activities are being carried out through collaboration with research institutions and official bodies in a number of developing countries.

Collaboration has been established between the Centre and institutions in Africa, Asia and Latin America.

Environmentally Sound Energy Development for India. Work started in 1992 on a UNEP- sponsored project with the Tata Energy Research Institute (TERI), New Delhi as main implementing organization, and the Indian Ministry for Environment and Forests as the main government participant. The aim of the study is to identify and recommend alternative development paths that could be followed in each of the energy-producing and consuming sectors. The project comprises specific case studies to assess the environmental impacts of power sector developments, coal production and energy-intensive industries, as well as the impact of urban growth on energy demand and urban environment.

The study is expected to state clearly the choices that are available for development in India in terms of the structure of the economy, the technological status of the options and the natural resource and capital requirements. This energy-environment policy project in India represents the first major activity in the energy policy area between the Centre and an institute in a developing country. The Centre supports the project through direct participation, provision of tools such as the Environmental Database (EDB), sharing of experience and informal training in India and at the Centre.

Work on the project during the year consisted primarily of (1)establishing working groups, composed of TERI staff, including the central coordination group for each of the ten components of the study, (2)formulating detailed work programmes for these components, and (3) initiating the data collection and other background activities. A first coordination meeting between UCC and the TERI project leadership took place in New Delhi in October 1992. This involved discussion of the proposed work programmes for the project components, as well as the requirements for transferring planning tools such as EDB. Close contact will be maintained between UCC and TERI throughout the duration of the project to the end of 1994. This is likely to involve semi-annual visits of UCC staff to New Delhi.

Energy and Environment in Latin America. Collaboration has been initiated with several institutes in Latin America, and Centre staff have visited a number of these countries during 1992 with the express purpose of identifying requirements and defining the form of future work, as well as contributing to regional training programmes.

A new collaborative project in Argentina has been started with the Instituto de Economía Energética (IDEE) as implementing organization. The aim of the collaboration is to develop methodological guidelines for providing energy planners in Latin America with the criteria for assessing both environmental impacts and macroeconomic effects of energy policies at national level. In the first stage, focus will be on the critical analysis of present criteria and on a first approach to the formulation of new criteria and methods and their application to the Argentine context.

The project will benefit from and supplement UCC's involvement in other national energy- environment studies and act as a test case for an extensive proposed project prepared jointly with the Latin American Energy Organisation (OLADE).

Collaboration with the National Energy Institute in Ecuador (INE), partially supported by the CEC, is nearing completion with the transfer and adaptation of the Environmental Database (EDB) to the Ecuadorian context. INE has started to develop inventories of present and projected emissions and environmental impacts as well and has also carried out environmental assessments of alternative future energy paths.

5.2 UNEP Greenhouse Gas Abatement Costing Studies

The UNEP Greenhouse Gas Abatement Costing project was initiated in 1991 to clarify the economic issues involved in assessing the costs of limiting greenhouse gas (GHG) emissions and to propose approaches for carrying out comparable costing studies. The project is coordinated by the Centre, with assistance from the Tata Energy Research Institute, India, Caminus Energy Ltd in Cambridge, UK and Dr Michael Grubb of London's Royal Institute of International Affairs.

The primary focus is to examine how the impact of varying degrees of abatement on key cost indicators can be assessed, in ways which (1)command a broad consensus as providing reasonable indications of the costs involved in limiting emissions, and (2)are practically realizable in relation to the available models, data and institutional capacities in the countries involved.

The first phase of the project, which was completed in 1992, consisted of detailed studies of the underlying issues in estimating abatement costs, including an analysis of modelling options and reviews of existing cost estimates, and a small set of national reviews. These country reviews aimed at establishing the status of analysis and data in the countries concerned, and illustrate in depth the practical issues raised in embarking upon abatement costing studies in widely diverse countries.

The country case studies of Zimbabwe, India, the Netherlands and Denmark have identified some very important practical problems in abatement scenario construction and cost assessment. For Zimbabwe and India as developing countries, appropriate emission forecasts, and energy and economic system data are not presently available and must be built up as part of the abatement costing study. For the Netherlands and Denmark a great deal of useful data and models exist, and efforts are already well under way to link technical-economic and macroeconomic models and to analyze regulation schemes in detail.

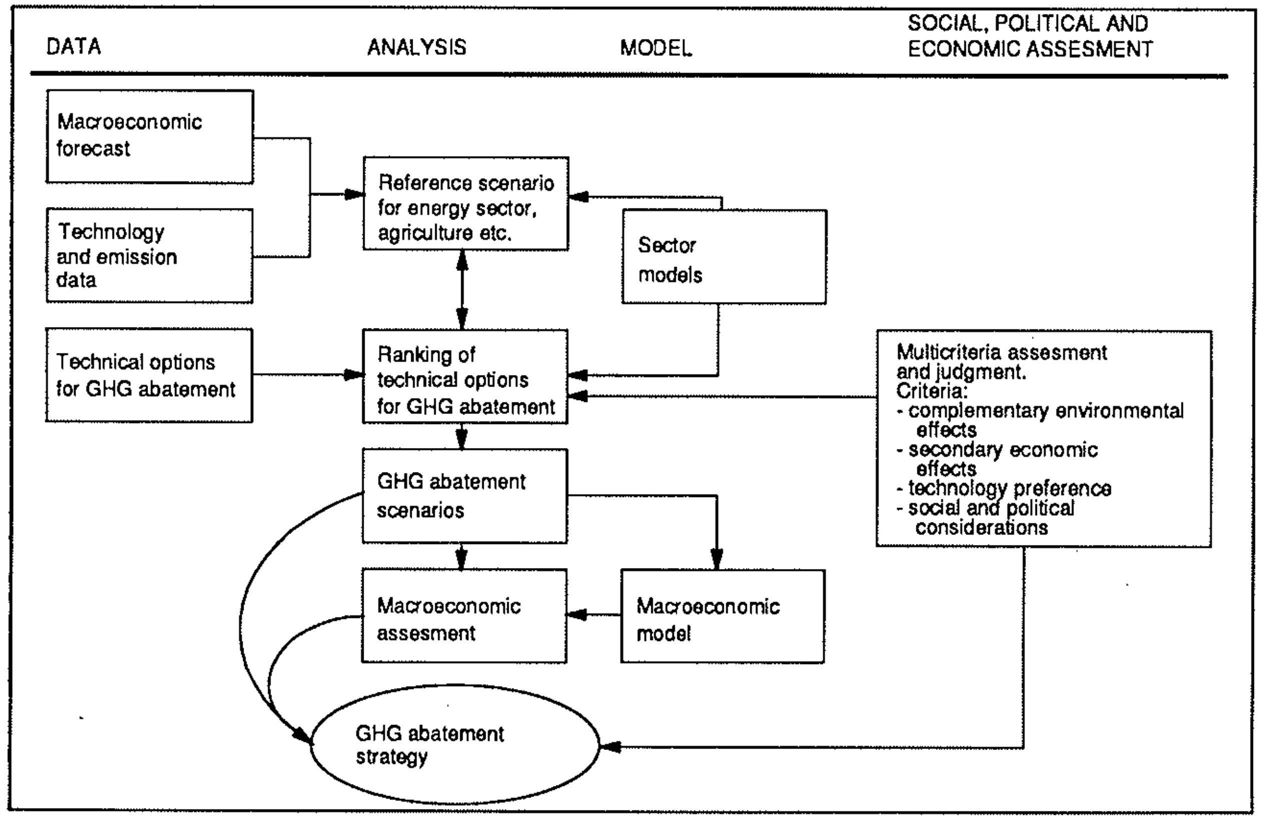
Phase One was concluded in June 1992 with a workshop held at Risø at which teams from the participating countries discussed the draft Phase One Report and the proposed guidelines for Phase Two. The Phase Two Guidelines were distributed to country teams in September 1992 and constitute the common framework for the country studies which are now under way. These guidelines will be further refined as the project proceeds and practical experience is accumulated.

The aim of Phase Two is to develop and test a methodological approach through a set of national case studies, using compatible assumptions for parameters like international fuel prices, discount rates, emission factors, and general technological development within the energy sector. In addition, the structure of the analysis (e.g. time horizons and degrees of abatement considered) and the concepts of cost used are defined to allow maximum comparability.

An essential feature of the case studies is the combination of the results of engineering (bottom-up) models, used for detailed system modelling of GHG abatement scenarios, with short to medium-run macroeconomic (top-down) models, in order to calculate the total macroeconomic effects of such strategies. This will involve improvement and utilization of the methodology of GHG-reduction cost curves.

Figure 5.1 gives a schematic representation of the proposed approach for the national case studies. This structure can be briefly summarized in the following steps:

Figure 5.1. Structure of proposed abatement analysis procedure.



1. Establish a reference scenario on the basis of the best available national macroeconomic forecast, technology and emission data. An energy system model (and possibly other sector models) is required in this step.
2. Specify a set of relevant GHG abatement technologies and make a separate direct cost and emission ranking of these compared with the reference scenario. Supplement the »pure« cost and GHG emission criteria with other relevant social, political, and economic criteria.
3. Analyze a set of comprehensive GHG abatement scenarios using a total energy system model and other relevant sector models, in which all relevant linkages in the production system can be treated.
4. Assess the macroeconomic impacts of the different GHG abatement scenarios derived in the previous step. At this stage some additional scenarios may be developed and analyzed using the sector models.

The initial group of four countries was joined for Phase Two by Brazil, Egypt, France, Senegal, Thailand, USA and Venezuela. The inclusion of these countries, and possibly more, to carry out comparable national studies of the cost of greenhouse gas limitation will provide valuable information on the feasibility of a common approach. The second phase of the project is scheduled to be completed in June 1993.

A possible third phase under preparation would extend the approach to an even wider group of countries, concentrating on establishing and consolidating local expertise in the assessment of such costs, as well as considering possibilities for intraregional cooperation.

Publication in 1992: 13.

5.3 Environmental Database

The availability of data on the different pollutants associated with energy use is a vital aspect of energy-environment planning. In order to select the most environmentally sound energy options, the energy planner must have a detailed knowledge of how the alternatives affect the environment.

The principle aim of UNEP in the energy field is to encourage greater environmental awareness and capabilities in developing countries. Making appropriate environmental information available to developing country energy institutions is therefore a high priority and this is being done through establishing a database of energy-environment information and disseminating it to relevant institutions in developing countries.

The Centre has joint responsibility, along with the Stockholm Environment Institute's Boston Centre (SEI-B), for the database of environmental factors associated with energy production, conversion and consumption. The UNEP/SEI-B Environmental Database (EDB) provides a systematic collection of information on the environmental effects of different energy forms and technologies.

EDB can be used either as an independent reference tool for environmental loading factors or as an integrated component of an energy model, allowing the user to calculate the total environmental loading of a chosen energy scenario. The database was designed to be linked to the LEAP energy modelling system (SEI-B, 1992) which is being used in several countries within the UNEP National Greenhouse Gas Abatement Costing project and in other collaborative efforts.

Construction of the database involved collecting environmental information associated with the wide variety of energy production and consumption technologies which are in use in developing countries, or which may be implemented in the future. Thus, the database includes environmental factors for commercial energy technologies using fossil fuels, such as power plants, boilers and motor vehicles. Such technologies are essentially the same as those used in industrialized countries, although account has to be taken of different maintenance and running conditions. In addition, the database includes information associated with the environmental effects of energy technologies not generally found in the industrialized countries on a large scale, such as biomass use in cooking stoves and charcoal production.

The initial data included in EDB was based primarily on those from the US Environmental Protection Agency and generally reflected US technologies, although some developing country data were also included. EDB activity is now concentrated on extending the coverage of the database by incorporating data from other emission data sources in order to increase the usefulness of the tool. Work on EDB in the Centre in 1992 was mainly devoted to extracting relevant information from the European CORINAIR emissions inventory (CEC, 1992), restructuring these data as approriate and entering them in

EDB. The CORINAIR inventory incorporates a comprehensive collection of emission factors for the important airborne pollutants. These factors are highly detailed according to energy technology, including power capacity and mode of operation, and provide a valuable addition to the data already included in EDB.

A stand-alone version of EDB, containing a preliminary version of the CORINAIR data, was distributed to a number of institutions in developing countries under a licence agreement.

5.4 Collaboration with the UN

One of the main tasks of the Centre is to provide support to UNEP in the area of energy and environment. The interaction has been intensive both on ad hoc tasks related to various types of requests for UNEP information and support, participation in meetings and conferences and preparation of consolidated statements and substantive reports.

In addition, the Centre has together with UNEP established a basis for a project collaboration with the National Environment Protection Agency in China. A proposal has been prepared for UNEP and is awaiting final approval. Similarly a new proposal for further development of the Environmental Database by SEI-Boston has been prepared by the Centre for UNEP funding.

A considerable effort has been invested in supporting UNEP's participation in the global warming programme under the Global Environment Facility (GEF). The GEF is established as a joint programme between the World Bank, UNDP and UNEP to assist developing countries in dealing with four major global environment problems including global warming and GHG emissions. Financial support is provided to developing countries for technical assistance activities, investment projects and to a limited extent strategic studies.

The Centre has assisted UNEP's GEF office in reviewing all the projects under the global warming programme and provided comments and suggestions to help arrive at decisions of the Interagency Committee governing the facility. In addition Centre staff have participated in meetings and seminars where the GEF programme has been presented and the criteria for project selection developed and discussed.

In order to facilitate contacts with relevant World Bank and UNDP staff, UNEP's GEF office has funded Centre staff consultations in New York and Washington. This has not only improved the quality of the participation in the review process, but also led to better and more direct contacts with the relevant programmes and staff members in UNDP and the World Bank.

5.5 Energy and Environment in Africa - Development of a New Strategy

Biomass dominates the energy sector in Africa, accounting for 50% to 90% of total national energy supply in many countries. Although biomass can be an environmentally sound source of energy for the region, current practices of biomass production, transformation and utilization are unsustainable, and have serious adverse effects on the environment.

Overdependence on biomass in its traditional form means that the per capita consumption of modern energy form in sub-Saharan Africa is less than half the average of developing countries, making it the lowest in the world. Large disparities exist among countries in the region, and between the underprivileged rural and urban poor and the higher income groups within countries.

Africa urgently requires a substantial expansion of energy services, but an indiscriminate expansion of the energy sector would be certain to entail severe economic and environmental costs. Therefore a new energy strategy must be evolved, making the most of the region's limited financial resources and minimizing the negative impacts of energy production and use.

A group of high-level African energy experts met in Nairobi from 18 to 20 May 1992 to evolve such a strategy. The experts' meeting on »A New Environmentally Sound Energy Strategy for the Development of Africa« was organized jointly by African Energy Policy and Research Network (AFREPREN), the Foundation for Woodstove Dissemination (FWD), UNEP and the Centre, which provided financial support for the meeting. Participants included representatives from governments, universities and research institutes in Botswana, Ethiopia, Ghana, Kenya, Nigeria, Sierra Leone and Uganda, as well as ENDA-TM (Senegal), the African Development Bank and the organizing institutions.

The primary role of the Centre was catalytic, helping to bring together highly qualified local experts to discuss common problems and their solutions, providing technical and financial support, and presenting the initiative within a high-level international setting.

The meeting resulted in a broad statement with the following five elements:

- Policies and Institutions,
- Mobilization of financial resources,
- Management, training and technology acquisition,
- Energy efficiency, and
- Enhanced supply of modern fuels.

The full strategy document was distributed to relevant institutions within and outside the region. The proceedings of the meeting, consisting of national position papers and overview presentations were edited into book form by the Centre and FWD, and will be published early in 1993. The meeting also produced several proposals for specific follow-up activities. Support will be sought from bilateral and multilateral organizations to implement the projects for groups of African countries. In all cases the emphasis will be on the use of local expertise. The Centre will continue to play a catalytic role in the projects and the continuing development of the strategy, and will offer and organize specific methodological support where required.

An immediate indirect result of the meeting was a request from the Swedish Agency for Research Cooperation (SAREC) to participate in an evaluation of AFREPREN. The network was established with financial support from SAREC in 1989 and the second phase of the programme was initiated recently. In conjunction with this support, SAREC has called for an independent evaluation of the performance of the network, partly to assess the preliminary results, and also to make recommendations on the future development and role of the network.

Publication in 1992: 14.

6 Conferences, Publications, Lectures and Committees

6.1 Conferences

In 1992 the department was strongly involved in organising the European Safety and Reliability Conference '92. The conference was the first Pan-European Conference on safety and reliability under the auspices of ESRA (European Safety and Reliability Association), and the preparation started more than four years ago when DGXII/ESRA under the Commission of the European Communities launched an initiative encouraging organizers of European conferences on safety and reliability to join their efforts in order to have one annual wide-scope European conference.

The conference was organized by Risø National Laboratory on behalf of SRE-Scandinavia (Society of Reliability Engineers, Scandinavian Chapter) with support from several European societies and organizations. It attracted about 275 delegates representing most European countries and a number in Asia, and North and South America. Industries as well as authorities, universities and research institutions were well represented.

The conference took place 10-12 June 1992 and the theme of the conference was »Safety and reliability: enhancement of competitiveness and environmental preservation«. The intention was to present all aspects of safety and reliability from quality, design, product liability, reliability and maintainability to safety of equipment and systems and risks to technical systems, health and the environment. There were 75 oral presentations of which two were invited keynote papers. In addition, a number of papers were presented at a poster session and during panel discussions. The presentations covered theoretical aspects, model developments and case studies. The conference was organized in a number of sessions dealing with computerized tools for risk and reliability analysis, risk assessment, human factors, reliability and quality in design, risk management, life cycle costs, component reliability, risk analysis methods, safety and the environment, structural reliability, systems reliability, reliability theory, software reliability, data collection and analysis and maintenance.

In the sessions dealing with risk analysis methods and tools there was an emphasis on integration of computer-based risk and reliability analysis in risk management-related decision support systems. The STARS project was presented as a contribution to these sessions. Risø's work on analysis of combustion products from warehouse fires was presented in a session on safety and the environment. The presentations on systems reliability ranged over a variety of aspects including safety analysis of procedures, the use of cause-consequence diagrams for the reliability analysis of sequentially operating systems and reliability analysis of the Great Belt Link in Denmark.

Conference proceedings containing the full text of most of the presentations can be ordered from Elsevier Science Publishers Ltd.

6.2 Publications

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10. **Brehmer, B.; Løvborg, L.; Winman, A.**, Learning the time constants of a dynamic task. (Centre for Cognitive Science. University of Roskilde, Roskilde, 1992) (Working papers in cognitive science and HCI. WPCS-92-6) 11 p.

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Schmidt, K., Mechanisms of interaction in CSCW. CoTech general meeting. CEC DGXIII, Brussels (BE), 13-14 Feb 1992. Unpublished. Abstract available.

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Sørensen, C.; Borstrøm, H., Cooperative design for manufacture. Integrated production systems research seminar, Ebeltoft (DK), 5-7 Oct 1992. Unpublished. Abstract available.

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6.4 Committees

Danish:

1. Research committee, Energy and Society (Min. of Energy). Hans Larsen.
2. Inter-ministerial committee on energy policy in the EC (Min. of Energy). Niels J. Thomsen.
3. Steering committee, Danish Society for Risk Assessment. Palle Christensen.
4. Environmental Appeal Board. Dan S. Nielsen.

5. Committee on standards for risk analysis (Danish Society of Chemical, Civil, Electrical and Mechanical Engineers). Kurt E. Petersen.
6. Board of Governers, Energy Centre Denmark. Hans Larsen.
7. Electricity forecasting group (Min. of Energy) Poul E. Morthorst.
8. Danish Council for Renewable Energy. Poul E. Morthorst.
9. Board of management, Centre for Cognitive Informatics). Hans Larsen.
10. Committee on Research and Development (Federation of Danish Trade Unions). Kjeld Schmidt.
11. Steering Group, Framework Programme on Representation and Processing of Knowledge (Danish Research Council for the Humanities). Leif Løvborg.
12. DANFIP Board of Danish IFIP TC-Representatives. Leif Løvborg.

International:

1. CGC-5 Nuclear fission energy, safety (C.E.C.). Hans Larsen.
2. Editoral board, Journal of Loss Prevention in the Process Industries. Birgitte Rasmussen.
3. Coordinator, CoTech WG4 'Developing CSCW Systems: Design Concepts'. Kjeld Schmidt.
4. Committee for European Standards on Nuclear Electronics (C.E.C.). Palle Christensen.
5. Steering committee, SHARE (Safety Management and Hazard Assessment Research Cooperation in Europe, C.E.C.). Kurt E. Petersen.
6. United Nations Solar Energy Group for Environment and Development. John M. Christensen.
7. Management and Policy Committee for UNEP Collaborating Centre on Energy and Environment. Hans Larsen (Chairman), John M. Christensen.
8. Halden Programme Group (OECD). Hans Larsen.
9. Editoral Board, Reliability Engineering & System Safety. Kurt E. Petersen.
10. TELEMAN User Group (C.E.C.). Kurt E. Petersen.
11. Programme Committee for the European Safety and Reliability Conference '92, June 1992, Denmark. Hans Larsen (Chairman).
12. Organizing Committee for the European Safety and Reliability Conference '92, June 1992, Denmark. Kurt E. Petersen (Chairman).
13. Steering Committee, Society of Reliability Engineers Scandinavia. Kurt E. Petersen.
14. Programme Committee for ESREL-93 Reliability Conference, May 1993, Germany. Kurt E. Petersen.
15. Editoral Board, An International Journal of Computer Supported Cooperative Work. Kjeld Schmidt.
16. Management Committee of COST Action 14 »Co Tech«. Kjeld Schmidt.
17. Model Evaluation Group (C.E.C.). Kurt E. Petersen (Chairman).
18. Programme Committee for the conference on Medium and Large Scale Biogas Plants In Developing Countries, Arusha, Tanzania, December 1993. John M. Christensen.
19. International Advisory Committee for a Workshop on Global Warming Issues in Asia, Asian Institute of Technology, September 1993. John M. Christensen.
20. Steering Committee for the Asian Energy Institute network project on »Asia's and Brazil's contribution to GHG emissions and policy responses for their minimization«. John M. Christensen.
21. World Energy Council Study Committee on Renewable Energy Resources. John M. Christensen.
22. World Energy Council Programme Committee on Energy Issues of Developing Countries. John M. Christensen.
23. IFIP Technical Committee TC.13 on Human-Computer Interaction. Leif Løvborg.
24. Member of Programme Committee for Workshop on CSCW Design, Schaerding, Austria, 1-3 June, 1993. Kjeld Schmidt.
25. Member of Programme Committee for Workshop on Social Science Research, Technical Systems and Cooperative Work, Paris, 8-11 March, 1993. Kjeld Schmidt.
26. Member of Programme Committee and Proceedings Chair for Third European Conference of CSCW, Milano, September 1993. Kjeld Schmidt.
27. Member of the Board of the Foundation of Co-operative Work Technology. Kjeld Schmidt.

7 STAFF

Hans Larsen, M.Sc. (Elec. Eng.), Ph.D. The Technical University of Denmark 1972. From 1973 to 1976 at Dragon project at AEE Winfrith, U.K. Risø from 1976. Energy Technology Department 1976-80, working with systems reliability. Head of Energy Systems Group 1980- 84. Head of Systems Analysis Department from 1985.

Cognitive Systems Group

Leif Løvborg, M.Sc. (Elec.Eng.) Risø from 1962. Radioisotope techniques (1962-66), nuclear geophysics and mineral exploration (1967-86). Group Leader (Electronics Dept.) 1965-86. Cognitive engineering research from 1986. Acting head of Cognitive Systems Group 1990-92. Head of this group since April, 1992. Coordinator of Risø's contribution to the activities within Centre for Cognitive Informatics. Main research activity: Experimental investigation of human cognitive behaviour in simulated »microworlds«.

Henning Boje Andersen, M.A. (Philos.) Copenhagen University and Oxford University (logic, philosophy of language) 1976-79. Medical Faculty, Copenhagen University and Roskilde University (philosophy of science) 1980-83. Risø from 1984, Cognitive Systems Group from February 1990. Main activities: Human-computer interaction, systems support of emergency management and multi-user training, modelling temporal reasoning, and communication failures.

Verner Andersen, M.Sc. (Elec.Eng.), Senior Scientist, Ph.D. Risø from 1966. Nuclear physics (1966-76), plasma physics (1976-86). Leader of programme on plasma-physics technology 1983-86. Information technology from 1986. Coordinator of the joint Nordic programme for nuclear emergency management (1986-90). Manager of CEC Esprit Action 2322, »IT Support for Emergency Management« (ISEM) (1989-1992). Cognitive Systems Group from February 1990 (as Project Leader). Manager of CEC Environment Action EV5V CT92 0070 »Multi-User System for Training and Evaluating Environmental Emergency Response« (MUSTER). Main activity: Project management, systems development.

Peter H. Carstensen, M.Sc. (Com. Sc.). Dansk Datamatik Center 1984-1988, Labour Unions Centre for Informatics 1989-1991. Cognitive Systems Group from February 1992. Main activities: Human-computer interaction, methodologies for analysis of work in complex settings, system development methodologies.

John Paulin Hansen, M.Sc. (Psychol.). Major subject: Visual perception, recording of eye movements, evaluation of interfaces, cognitive modelling. Ph.D. student at Risø from 1988. Subject: Perception and cognition in complex work situations.

Michael May, M.Sc. (Psychology & Cultural Sociology, 1985), Ph.D. (under evaluation, spring 1992). Risø from 1991. Psychological Laboratory, University of Copenhagen (1987-1990), Centre for Cognitive Science, University of Roskilde (1990-1991). Main research interests: cognitive semantics, logical semantics, semiotics & AI. Main activities: Taxonomy of graphical objects in HCI, Semantic analysis of computer interfaces, Semiotic theory of multimedia design.

Finn R. Nielsen, M.Sc. (Appl. Math. & Phys.). Technical College of Copenhagen 1968-74. Risø from 1974. Computer programming for models and graphical interfaces within manmachine studies and operator support facilities, simulation of power plants for diagnosis and control (1974-1989). Cognitive Systems Group from February 1990. Main activities: Cognitive simulation, implementation of design concepts.

Annelise Mark Pejtersen, M.A. (Sci. of Lit.). University of Copenhagen 1971-73, Associate Professor at the Royal School of Librarianship 1971-82, Acting Professor 1983-85. Visiting Senior Research Scientist at Georgia Institute of Technology 1982-83. Risø from 1986 (as Project Leader). On leave as manager of the Labour Unions' Centre for Informatics 1989-90. Cognitive Systems Group from February 1990. Main activities: Project management, user modelling, ecological design concepts, multimedia interfaces, taxonomy of work domains. Annelise Mark Pejtersen received in 1992 the P.F. SUHM reward for her research on user centret Library systems.

Kjeld Schmidt, M.Sc. (Sociol.), Senior Scientist. Roskilde University 1972-85, Dansk Datamatik Center 1985-88, Labour Unions' Centre for Informatics 1989-90. Cognitive Systems Group from March 1990. Main activities: Theory and methodology for analysis of cooperative work in complex settings, Computer-Supported Cooperative Work, taxanomy of work domains.

Carsten Sørensen, M.Sc. (Com. Sc. with Math.), Ph.D. Department of Mathematics and Computer Science, Aalborg University 1989-1992. Cognitive Systems Group from September 1992. Main activities: Computer Supported Cooperative Work, computer support of integration of design and process-planning in manufacturing (Design for Manufacture).

Steen Weber, M.Sc. (Elec.Eng.), Ph.D. Risø from 1972. Computer codes for nuclear fuel management (1974-75). Risk Analysis Group (Dept. of Energy Technology) 1975-84, Acting Group Leader 1982-83. Core simulator project, risk analysis of off-shore platforms. Development and use of codes for fuel management in collaboration with Danish utilities (1984-87). Leader of project on knowledge-based system for control of heat distribution (1988-89). Cognitive Systems Group from February 1990. Main activity: Advanced interfaces and databases for information retrieval systems. Project leader KAVAS-2 1992-.

Energy Systems Group

Niels Juhl Thomsen, M.Econ. Danish Ministry of Education 1978-79, Danish Ministry of Housing and Building 1979-81, Danish Ministry of Energy 1981-89. Joined Risø as Head of Energy Systems Group in May 1989. Main activities: General energy planning and economics of renewable energy.

Frits Møller Andersen, M.Econ., Senior Scientist. Specialized in econometrics and macroeconomic modelling. Research assistant Århus University 1978. Assistant planner in local government 1979. Risø from 1980 until September 1992. Main activities: The macro-sectoral model HERMES for Denmark and a technical-economic model for the Danish industrial energy consumption.

Peter Skjerk Christensen, M.Sc. (Elec.Eng.), Senior Scientist. Risø from 1958. Nuclear research and education (1958-69), reactor engineering and thermohydraulics including simulation models (1969-76), Energy Systems Group from 1977. Stationed in Cape Verde Islands as energy advisor to the government (1991). Main activities: Energy systems modelling. Renewable energy technologies. Energy planning in Eastern Europe and CIS.

Jørgen Fenhann, M.Sc. (Physics with mathematics and chemistry), Senior Scientist. Niels Bohr Institute 1977. Risø from 1978. Main activities: Development of energy planning models, economics of new and renewable energy technologies, calculation of emission from energy system, and energy-environmental planning for Eastern European and developing countries.

Poul Erik Grohnheit, M.Econ., Senior Scientist. Danish Building Research Institute 1969-71, town planning consultant 1971-72 and 1979-80, economic planning and budgetting in local government 1973-79. Risø from 1980. Main activities: Energy system modelling, economics of electricity generating systems, and electricity markets.

Kirsten Halsnæs, M.Econ., Senior Scientist. Danish Ministry of Housing and Building 1983-87. Risø from April 1987. Main activities: Integrated energy and environmental models, integrated models, environmental economics, economic analysis of greenhouse gas abatement.

Lotte Schleisner Ibsen, M.Sc. (Mech.Eng.), Senior Scientist. Risø from 1984 in Research Section of the Engineering Department working on aquifer thermal energy storage. Joined Energy Systems Group in 1989. Main activity: Assessment of energy technologies and long-term energy technologies.

Niels A. Kilde, M.Sc. (Chem.Eng.), Senior Scientist. The Danish Steelworks Ltd. 1962-81. Research and quality control (1962), planning and administration (1967), casting department manager (1972), development and energy manager (1977). Risø from 1981. Main activities: Energy use in industry and transport, emissions inventory.

Helge V. Larsen, M.Sc. (Elec.Eng.), Ph.D., Senior Scientist. Technical University of Denmark 1974. Storno A/S from 1975. Risø from 1976. Department of Reactor Technology 1976-77. Energy Systems Group from 1977. Main activities: CHP production, modelling of energy systems, economic models for the oil and gas sector, development of planning models for wind energy.

Poul Erik Morthorst, M.Econ., Senior Scientist. Economist specialized in econometrics and macro-economics. Risø from 1978. Head of Energy Systems Group 1985-89. Main activities: General energy planning and modelling with emphasis on forecasting electricity demand forecasting, economics of renewable energy technologies, especially wind turbines.

Lars Henrik Nielsen, M.Sc. (Phys.,Math.), Senior Scientist. Risø from 1981. Main activities: Probabilistic methods and model development, technical-economic modelling, and assessment of energy technologies, especially renewable energy, emissions calculations.

Peter Stephensen, M.Econ. Ph.D. Student at Institute of Economics, University of Copenhagen 1989-91. Specialized in theoretical economics. Risø from 1991. Main activities: Environmental economics and macro-economic models.

Risk Analysis Group

Kurt Erling Petersen, M.Sc., Ph.D. Risø from 1977. Department of Energy Technology 1977-84. Risk Analysis Group from 1984. Head of Risk Analysis Group from 1990. Deputy head of Systems Analysis Department. Main activities: Risk and reliability analysis, tools for operation and maintenance and treatment of reliability data.

Palle Christensen, M.Sc. (Elec.Eng.). Risø from 1962. Electronics Department 1962-86 working on nuclear instrumentation, research instrumentation and reliability projects. Department of Information Technology 1986-88 working on knowledge-based computing. Secretary of Risø's patent council 1973-88. Risk Analysis Group from 1988. Main activity: Development of computer codes for reliability, and safety analysis.

Carsten D. Grønberg, M.Sc. (Elec.Eng.). Risø from 1967. Electronics Department 1967-78. Safety Department 1978-83. Risk Analysis Group from 1984. Main activities: Human factors, emergency planning, risk communication, risk management.

Hans E. Kongsø, M.Sc. (Mech.Eng.). Risø from 1957. Research reactor DR 2 1957-63, Department of Energy Technology 1963-84. Risk Analysis Group from 1984. Main activities: Computer codes for reliability and consequence assessment, and reliability and risk assessment of nuclear and industrial plants.

Kurt Lauridsen, M.Sc. (Elec.Eng.), Ph.D.(Nuclear engineering). Risø since 1974. Department of Energy Technology 1974-87, working with nuclear safety and industrial risk analysis. Department of Informatics 1987-90. Risk Analysis Group from March 1990. Main activities: Reliability analysis, risk management.

Dan S. Nielsen, M.Sc. (Elec.Eng.). Risø from 1962. Electronics Department 1962-84. Risk Analysis Group from 1984. Main activities: Risk analysis of individual plants, physical modelling for consequence assessments.

Søren Ott, M.Sc. (physics), Ph.D. (Turbulence theory). Risø from 1985. Main activities: Models and computer codes for consequence assessment; dense gas dispersion and flame experiments.

Jette Lundtang Paulsen, M.Sc. (Mech. Eng.). DTH 1972. From 1972-80: Research reactor DR3. From 1980-86: Uranium Extraction project. From 1986-90: Department of Informatics. From 1990: Department of Systems Analysis. Main activities: Maintenance planning, software development, interface systems.

Birgitte Rasmussen, M.Sc. (Chem.Eng.), Ph.D. The Technical University of Denmark from 1981-84. Risø from 1984. Main activities: Risk assessment of industrial activities, risk management, risk communication.

Lene Smith-Hansen, M.Sc. (Chemistry). Risø from 1986. Main activities: Risk assessment of chemical plants, toxic effects from releases and quantitative assessment of toxic chemical substances from combustion.

UNEP Collaborating Centre on Energy and Environment

John Møbjerg Christensen, M.Sc. (Eng.) Ph.D. Danish National Agency of Technology 1980-83, R&D initiation and administration, Oilconsult, Consulting Engineers and Planners 1983-84, R&D Energy Planning, NRSE projects. Risø from 1984. Energy Systems Group 1984-88, Energy planning in developing countries, project analysis tools and methods. Programme Officer, Energy Unit, United Nations Environment Programme 1988-90. Head of UNEP Collaborating Centre on Energy and Environment from October 1990. Main activities: energy- environment planning in developing countries, project initiation, UN contacts and coordination.

Camilo Jose C. Lim, Jr., M.A. (Dev.Econ.) Risø from June 1991 until October 1992. International experience in energy policy, planning and research. Previous posts as economist with the Philippine government and researcher at the Asian Institute of Technology (Thailand). Main activities at the Centre include energy and environment planning, policy research, and project evaluation; model and database development and use.

Gordon A. Mackenzie, B.Sc. Ph.D. (Physics), Senior Scientist. Guest researcher at Risø 1974-78. Lecturer at Edinburgh University 1978-79. Energy Systems Group from 1980. 1984 to 1987 Energy Adviser/Deputy Director at Department of Energy, Zambia. From February 1988 until February 1990 leader of Environmental Modelling Group. From October 1990 with UNEP Collaborating Centre on Energy and Environment as senior energy planner. Main activities: integrated energy/environmental models, energy and environment in developing countries, environmental database.

Arturo Villavicencio, M.Sc. (Math.) National Energy Institute (Ecuador) 1979-85. Energy Planning Consultant for the Latin American Energy Organisation, CEC and World Bank 1985- 88. Energy Adviser at OLADE 1988-90. From May 1991 with UNEP Collaborating Centre on Energy and Environment. Main activities: Energy/environmental models, integrated energy- environment planning in Latin America.

Postgraduate Students

Hans Henrik Krogh Andersen, M.Sc. (Psychol.). Major subject: Cooperative management of classification schemes in electronic publishing, cooperative work, work analysis. Ph.D. student at Risø from February 1992. Subject: Computer-supported distributed cooperative manipulation of social mechanisms of interaction.

Lis Ketscher, M.Sc. (Psychol.). Danish Royal School of Education 1982-1985. Risø 1987-1988 as scientific assistant in a project on computer-assisted knowledge exploration, supported by the Danish Research Council for the Humanities. Main activities: Knowledge representation, knowledge structure, development of methods for probing mental models; problem solving and decision making. Ph.D. student at Risø from 1989 until March 1992. Subject: Knowledge aquisition and knowledge structures in computer-simulated task performance.

Anette Schnipper, M.Sc. (Pharm.). The Royal Danish School of Pharmacy 1989-90. Ph.D. Student at Risø from 1990. Subject: Toxic Products in Smoke from Chemical Fires.

Lene Sørensen, M.Sc. (Eng.). Major subject: Strategies for Controlling Danish Waste Water Plants. Ph.D. student at Risø from April 1990. Subject: Integrated Environ- mental Models and Uncertainty.

Guest Researchers

Jan Scherfig, Ph.D. (Civil Eng.) Professor of Environmental Engineering. University of California Irvine, 1969. University of California Scandinavian Study Center 1989-91. Main activities: Water reclamation and rinse, industrial waste treatment; entrophications, biomass control; economic analysis of waste treatment systems.

Antony Drapella. Technical University of Gdansk, Poland. March - May 1992. Participated in the work, mainly on development of a reliability model describing the impact of ionizing radiation on electronic components.

Stephen Karekezi. Visiting scientist at UNEP Centre, August 1992. Executive Secretary of the Foundation for Woodstove Dissemination and Facilitator of the African Energy Policy and Research Network (AFREPREN) based in Nairobi, Kenya. His main task during the stay was to edit the book »Energy Options for Africa« in collaboration with Gordon Mackenzie.

R.S. Maya. Visiting Scientist at UNEP Centre, December 1992 working closely with UNEP Centre staff on the UNEP GHG Abatement Costing Project and with ESG on the country study for Zimbabwe. Dr Maya is director of the Southern Centre for Energy and Environment in Harare, Zimbabwe.

Programmer

Søren Præstegaard, datanom. Regnecentralen 1973-79. Risø from 1979. Datanom with special subject: Optimization completed 1985 at EDP-school, Copenhagen. Working on simulation models, graphics, and general user support.

Secretaries

Maria M. Andreasen
Gytha Egelund
Jette Larsen
Annette Dahl Poulsen
Irma Strandvad

Research Technician

Erling Johannsen

Temporary Staff

Mette Olufsen (M.Sc. student), from Aug 15. Development of library database for UCC and integration of CORINAIR data in the EDB.

Steffen Willumsen Nielsen (information consultant) until 31 March. Software testing, user documentation, and evaluation of user performance under the BOOKHOUSE project.

Henrik Garde, M.Sc. (Comput.Sci.), from 15 August. Development of software for message management system for emergency organizations.

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The report describes the work of the Systems Analysis Department at Risø National Laboratory during 1992. The Department is made up of the Cognitive Systems Group, the Risk Analysis Group, the Energy Systems Group and the UNEP Collaborating Centre for Energy and Environment. The report includes lists of publications, lectures and staff members.

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